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# THE JOURNAL OF DENTAL RESEARCH

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(Continuing the Journal of the Allied Dental Societies)

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**Public health aspects of dental decay in children.** Number III of School Health Research Monographs. By RAYMOND FRANZEN, Ph.D., Director of Research, School Health Study, American Child Health Association. 1930: pp. 121; 7 x 4½ in.; 2 charts, 10 graphs, and many tables. American Child Health Association, New York.

**Étude sur l'éclosion épidémique de l'influenza.** By JOHS. MYGGE. Supplement XXXII of *Acta Medica Scandinavica*, lxxiii, 1930; pp. 145; 7 x 4 in.; 5 illustrations.

**Zur Kenntniss der lokalisirten Thrombenbildungen in der Vena iliaca communis sinistra.** By ANDERS KRISTENSON. Supplement XXXIII of *Acta Medica Scandinavica*, lxxiii, 1930: pp. 82; 7 x 4 in.; 28 illustrations.

**Rickets including osteomalacia and tetany.** By ALFRED F. HESS, M.D., Clinical Professor of Pediatrics, University and Bellevue Hospital Medical College, New York City. 1929: pp. 485; 7¼ x 4 in.; 52 illustrations; $5.50. Lea and Febiger, Philadelphia, Pa.

**Synopsis of the practice of preventive medicine as applied in the basic medical sciences and clinical instruction at the Harvard Medical School.** By the FACULTY OF MEDICINE. 1929: pp. 194; 6½ x 3½ in.; no illustrations. Harvard University Press, Cambridge, Mass.

**La pratique stomatologique. IV. Dentisterie opératoire.** By POL NESPOULOUS, D.D.S. (College dentaire de Chicago), Professor à l'Ecole Francaise de Stomatologie; Stomatologiste des Hôpitaux de Paris. 1929: pp. 541; 6½ x 4 in.; 263 illustrations; 65 fr. Masson et Cie, Paris, France.

**Ueber die Natur der Muskelrheumatischen (myalgischen) Schmerzsymptome.** DR. FOLKE LINDSTEDT, Stockholm, Sweden. Supplement XXX of *Acta Medica Scandinavica*, lxxii, 1929: pp. 180; 7 x 4 in.; 13 illustrations.

**Testicular grafting from ape to man.** SERGE VORONOFF, Director of the Laboratory of Experimental Surgery of the Collège de France and Assistant Director of the Laboratory of General Biology of the Ecole des Hautes Études; and GEORGE ALEXANDRESCU, formerly assistant at the Institut d'Histologie, and Staff Hospital Physician, Bucharest, Roumania. *Translated* by THEODORE C. MERRILL, M.D. 1929: pp. 125; 6½ x 3½ in.; 39 illustrations. Brentano's Ltd., London, England.

**The properties and uses of drugs.** By HENRY H. RUSBY, Ph.M., M.D., D.Sc., Dean and Professor of Materia Medica, College of Pharmacy, Columbia University; A. RICHARD BLISS, JR., A.M., Phar. D., M.D., Dean of the School of Pharmacy, and Chief of the Division of Pharmacology and Materia Medica, Colleges of Medicine and Dentistry and School of Pharmacy, University of Tennessee; and CHARLES W. BALLARD, A.M., Phar. D., Ph.D., Associate Professor of Materia Medica and Director of the Microscopical Laboratory, College of Pharmacy, Columbia University. 1930: pp. 823; 7½ x 4½ in.; 38 illustrations; $6.50. P. Blakiston's Son and Co., Philadelphia.

**American illustrated medical dictionary.** A complete dictionary of the terms used in medicine, surgery, dentistry, pharmacy, chemistry, nursing, veterinary science, biology, medical biography, etc. By W. A. NEWMAN DORLAND, A.M., M.D., F.A.C.S., member of the Committee on Nomenclature and Classification of Diseases, American Medical Association, and Editor of the "American Pocket Medical Dictionary"; with the collaboration of E. C. L. MILLER, M.D., Professor of Bacteriology and Biochemistry, Medical College of Virginia. *Fifteenth edition.* 1929: pp. 1427; 8½ x 4½ in.; 525 illustrations; flexible binding—plain, $7.00; thumb index, $7.50. W. B. Saunders Company, Philadelphia and London.

**Dental bibliography.** A reference index to the literature of dental science and art as found in the Libraries of the New York Academy of Medicine and Bernhard Wolf Weinberger. Compiled by BERNHARD WOLF WEINBERGER, D.D.S., Librarian of the First District Dental Society; Advisory Librarian, Dental Library, New York Academy of Medicine. *Second edition.* 1929: pp. 183; 7½ x 4½ in.; no illustrations. Published under the auspices of the First District Dental Society of the State of New York, New York City.

**Deutsche Zahnheilkunde.** Heft 75. 1929: 8 x 4½ in.; marks 3.60. Georg Thieme, Leipsig, Germany. (1) Submaxillare Röntgenaufnahmen, ein neues Verfahren zur röntgenographischen Darstellung des Unterkiefers und seiner Zahne. By Dr. J. v. RECKOW, Marburg. Pp. 15; 30 illustrations. (2) Klinik und Diagnostik der Osteodystrophia fibrosa localisata der Kiefer. By Dr. KARL SPRING, Vienna. Pp. 15; 7 illustrations.

**Fundamentals of pathology.** By JOSEPH SCHROFF, B.S., M.D., D.D.S., Associate Professor of Oral Pathology, School of Dental and Oral Surgery, Columbia University. 1929: pp. 109; 7½ x 4½ in.; 40 illustrations; $2.50. William Albert Broder, New York City.

**Outline of bacteriology.** By HENRY A. BARTELS, B.S., D.D.S., Lecturer on Bacteriology, School of Oral Hygiene, Columbia University. 1929: pp. 128; 6½ x 4 in.; 47 illustrations; $2.00. William Albert Broder, New York City.

**Annual report (reprints) of the investigations carried out under the supervision of The Therapeutic Research Committee of the Council on Pharmacy and Chemistry of the American Medical Association.** *Volume XVII.* 1928: 16 reprints; 7½ x 4½ in.; 43 illustrations. American Medical Association, Chicago, Illinois.

**Dental histology and embryology.** By B. ORBAN, M.D., Professor of Dental Histology and Pathology, Chicago College of Dental Surgery, Dental Department of Loyola University. *Second edition.* 1929: pp. 218; 7 x 4½ in.; 201 illustrations; $4.00. P. Blakiston's Son and Co., Inc., Philadelphia.

**Four lectures on "local analgesia in dental practice."** Delivered, under the auspices of the Dental Board of the United Kingdom, by C. H. HOWKINS, F. N. DOUBLEDAY, F. ST. J. STEADMAN, and A. T. PITTS. 1929: pp. 119; 7½ x 4½ in.; 104 illustrations. Dental Board of the United Kingdom, 44 Hallam Street, Portland Place, London, W. I.

**Practical conclusions from scientific research in denture construction.** By ALFRED GYSI, D.D.S., M.D. (hon.), D.M.D. (hon.), Professor of Prosthetic Dentistry and Director of the Histological Laboratory, University of Zurich, Switzerland. 1929: pp. 40; 7½ x 4½ in.; 37 illustrations. Dentists' Supply Company of New York.

**The business side of dentistry.** By EDWIN N. KENT, D.M.D., Lecturer on conduct of practice, Harvard University Dental School. 1929: pp. 180; 6½ x 4 in.; 13 illustrations; $5.00. C. V. Mosby Co., St. Louis, Mo.

**A text-book of oral pathology for students and practitioners of dentistry.** By RUSSELL W. BUNTING, D.D.S., D.D.Sc., Professor of Dental Histology and Pathology, University of Michigan, Ann Arbor, Michigan. 1929: pp. 495; 7½ x 4½ in.; 327 illustrations; $7.00. Lea and Febiger, Philadelphia, Pa.

**Hygiene of the mouth and teeth.** By THADDEUS P. HYATT, D.D.S., F.A.C.D., Professor of Preventive Dentistry, New York University Dental School, and Assistant Medical Director, Metropolitan Life Insurance Company. 1929: pp. 64; 4½ x 2½ in.; 1 illustration. Brooklyn Dental Publishing Company, Brooklyn, N. Y.

# INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH

## SCIENTIFIC PROCEEDINGS OF THE CHICAGO SECTION[1] DECEMBER 16, 1929

STANLEY D. TYLMAN, B.S., D.D.S., F.A.C.D., *Editor*

*Scientific program*

Meeting held at the West Side Student Y. M. C. A. Building, Wood and Congress Streets, Chicago, December 16, 1929. *Chairman:* Edward H. Hatton, B.L., M.D., President of the Section.

I. Report of repair in a case of root resection of a chronically infected bicuspid tooth. *Edgar D. Coolidge*, D.D.S., B.S., F.A.C.D. ..... 133
II. The relationship, in jaw fractures, of infection, delay in reduction, syphilis, and blood calcium and phosphorus content, to the healing process. *Donald E. Woodard*, D.D.S. ..... 134
III. Adamantinoma. *Rudolf Kronfeld*, M.D. ..... 134
IV. The significance of an apparent shortening of an upper incisor. *Warren Willman*, B.S., D.D.S. ..... 135

## ABSTRACTS

### I. REPORT OF REPAIR IN A CASE OF ROOT RESECTION OF A CHRONICALLY INFECTED BICUSPID TOOTH

*Edgar D. Coolidge, D.D.S., B.S., F.A.C.D., Chicago College of Dental Surgery, Loyola University, Chicago, Ill.*

An upper bicuspid, showing bone resorption about its apex, was resected in 1914 and extracted in 1928 after giving efficient service for 14 years. Histologic sections indicated complete repair by a deposit of new cementum over the resected end of the root covering the exposed dentin as well as the original cementum. The end of the gutta-percha root-canal filling was covered by a dense fibrous band of connective tissue stretched across the canal-opening from cementum

[1] The last preceding series of abstracts of the proceedings of the Chicago Section was published in the *Journal of Dental Research*, 1929, ix, p. 609.

to cementum. No inflammatory cells were found in this tissue. The histologic evidence of complete repair in this case, by an overgrowth of cementum and connective tissue, proves that the treatment had been successful.

### II. THE RELATIONSHIP, IN JAW FRACTURES, OF INFECTION, DELAY IN REDUCTION, SYPHILIS, AND BLOOD CALCIUM AND PHOSPHORUS CONTENT, TO THE HEALING PROCESS[2]

*Donald E. Woodard, D.D.S., Cook County Hospital, Chicago, Ill.*

The subject was discussed under the following headings: Simple fractures; compound fractures; single, double, and triple fractures; syphilis; age; delay in reduction; methods of reduction; infection; blood calcium and phosphorus content; white blood-counts; x-ray results; red blood-counts; urinalysis; differential blood-counts. Graphs and slides illustrated the relationships. Infection, delay in reduction, syphilis, and blood calcium and phosphorus content, were studied most thoroughly because they were found to be the most important after many clinical and laboratory observations had been made. Such factors as type of fracture, age of patient, syphilis, delay in reduction, and methods of reduction, influence healing-time only in so far as they predispose to infection.

### III. ADAMANTINOMA

*Rudolf Kronfeld, M.D., Chicago College of Dental Surgery, Loyola University, Chicago, Ill.*

Adamantinoma is a soft, epithelial, benign tumor of the jaws. Histologically it shows a close relationship to the tooth germ and the dental lamina in the earlier stages of development, and results from pathologic overgrowth of these structures. Two main types of adamantinoma have been described: solid and cystic. A *solid* adamantinoma consists of a connective-tissue stroma, and numerous cords and strands of epithelium. Some show a differentiation into high cylindric cells (ganoblasts) and stellate reticulum. The *cystic*

[2] A thesis, submitted to Northwestern University for the M.S. degree, on approximately fifty consecutive cases at the Hospital.

type develops from the solid by cystic degeneration of the stellate reticulum. The cystic adamantinoma, or multilocular cystoma, consists of large epithelial cysts filled with a mucous liquid; and by its growth sometimes causes a very considerable bone resorption.

### IV. THE SIGNIFICANCE OF AN APPARENT SHORTENING OF AN UPPER INCISOR

*Warren Willman, B.S., D.D.S., Chicago College of Dental Surgery, Loyola University, Chicago, Ill.*

A boy of 14 had an upper, left, central incisor that seemed to be becoming shorter. It was a pulpless tooth with a good root-canal filling, and a porcelain dowel-crown—now over 2 mm. shorter than the adjacent central. Deep resorptions on the sides of the root had been replaced by bone, as shown in radiograms and microscopic specimens. This caused the tooth to be virtually ankylosed to the maxilla, thereby preventing it from erupting with the other teeth. The comparatively new concept that human teeth normally continue to erupt, at varying rates throughout life, has been demonstrated in histological specimens by the presence of bundle-bone and epithelial rests in the region of the apex. Clinically it has been more difficult to show, for want of a suitable fixed point from which to take measurements. For this reason the present case constitutes one of the few available clinical proofs of this biologic phenomenon.

# THE INTERRELATION OF MEDICINE AND DENTISTRY[1]

## A Symposium

RUSSELL L. CECIL, M.D.

*Cornell University Medical School, New York City*

AND

LEROY M. S. MINER, M.D., D.M.D.

*Harvard University Dental School, Boston, Mass.*

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## I. THE RELATION OF MEDICINE TO DENTISTRY

*Russell L. Cecil, M.D., New York City*

### *A. Introduction*

One of the most serious problems that face the medical profession today is that of maintaining some sort of liaison between the mother branch and the rapidly developing specialties. Indeed, these children of medicine are developing and multiplying at such a rate that the mother has been reduced almost to a skeleton. At the Cornell Clinic we often remark that, with the establishment of so many special

[1] Presented at a meeting of the New York Academy of Dentistry, Yale Club, Vanderbilt Ave. and 44th St., New York City, January 23, 1930.

clinics, the Department of General Medicine can now lay claim to nothing more pretentious than the two old stand-bys, constipation and neurasthenia. Even these two prevalent ailments could be confiscated by gastro-enterology and neurology, respectively, if they wished to claim their own. With a surprising generosity, however, they are perfectly willing to leave these two homely maladies to the general practitioner. But even if, as time goes on, all the ills of mankind eventually fall into some specialty, there will always be a need for men of wisdom and good judgment who can study the patient as a whole, and correlate the findings and therapeutics of the various specialists. This rôle will probably always be played by the general practitioner or the internist, a man whose knowledge of the various branches of medicine may perhaps be superficial, but who at least understands the general principles of pathology, symptomatology, and therapeutics, and who with this knowledge can weigh wisely the special problems that arise in the handling of his patient.

Dentistry is a special branch of medicine, and though now-a-days the two professions seem to have strayed apart, I believe that, as time goes on, this divergence will be corrected and dentistry will assume its logical place in the medical clinic. As a matter of fact, dentistry commands one of the most strategic positions in the whole medical field. Indeed, there is no department of medicine or surgery which does not come at some time or other into contact with it. I call this position of dentistry strategic, because the mouth, as the point of entrance into the human body, occupies by reason of this fact a strategic position. This applies particularly to that perhaps most important department of medicine, namely, the infectious diseases. In a course on infection and immunity that I give every year at the Cornell University Medical School, I emphasize this point to the students and point out the fact that were it not for this opening, this *crack*, in an otherwise intact and well-protected machine, man would be practically immune to the attacks of pathogenic bacteria. The human fetus is born with a sterile mouth and sterile gastro-intestinal tract. It is only after exposure to the outside world that the mouth becomes contaminated with bacteria. From then on, the fight is continuous throughout life, bacteria gaining access to the mouth and pharynx, and there attacking not only local structures

such as the tonsils, teeth, and sinuses, but making occasional inroads into the respiratory tract, the gastro-intestinal tract and, through the cribriform plate, the central nervous system. There are of course exceptions, such as venereal disease and certain infections of the skin, where bacteria enter the body by other channels, but these exceptions constitute a small minority. By far the greater part of all the infections that man is heir to can be traced directly or indirectly to the entrance of pathogenic bacteria into the mouth or naso-pharynx.

### *B. Focal infection*

The most important phase of medicine in relation to dentistry is of course focal infection. So much has been written or said on this subject that it has become somewhat threadbare as a theme for medical meetings. However, it is a problem in which I have always been greatly interested, and there are certain aspects of focal infection which I would like to discuss tonight. It is said that focal infection was first recognized by Benjamin Rush in 1818. The modern advocates of this theory, however, are Hunter in Great Britain and Frank Billings in the United States. Hunter really preceded Billings, for he began to talk on oral sepsis as early as 1898. Strangely enough, however, he makes no mention of its relation to rheumatic disease. In 1912 Billings made his first report on the relation of focal infection to arthritis and other allied conditions, and in the years following, he and his distinguished colleague, E. C. Rosenow, made many important contributions to this subject. Billings rightly stressed the importance of dental and tonsillar infection. Subsequent study has shown that these are by far the most important foci of oral sepsis.

As Haden points out, four types of dental infection may be associated with systemic disease: (1) Chronic periapical infection of pulpless teeth, (2) pyorrhea alveolaris and pus pockets around partially erupted teeth and under reconstructive appliances, (3) chronic pulp infection in vital teeth, and (4) residual alveolar infection after tooth extraction.

Chronic periapical infection is by far the commonest dental infection responsible for systemic disease. Such infections occur at some time or other in a large majority of adults. In such cases, radiographic findings nearly always show some departure from the normal.

There may be erosion of the bone at the apex of the tooth and replacement of the bone by granulation tissue. The finding of granulation tissue about infected roots is more common than the demonstration of a true abscess with pus formation. Oftentimes bacteria can be demonstrated at the root of a pulpless tooth when neither pus nor granulation tissue are present. It is for this reason that Rosenow condemns all devitalized teeth and believes that they are a constant menace to health.

As a rule pyorrhea alveolaris is not looked upon as such a serious source of systemic infection as the periapical abscess. Yet in deep pockets in which pus and bacteria are present under pressure, it seems reasonable to suppose that absorption may readily occur. The pockets around partially erupted teeth should be looked upon with special suspicion.

Chronic pulp infections in vital pulps occur more frequently than we suppose. As the carious process in the dentine approaches the pulp chamber, the pulp is often infected for some time before death of the pulp takes place. Haden states that chronic infections in vital pulps may exist for years.

The removal of an infected tooth does not necessarily remove the alveolar infection. Not infrequently root fragments and filling material remain after root extraction. If a piece of root or foreign body is left in an infected area, infection may persist for a long time. In such a case, extraction of the teeth accomplishes very little for the patient.

### *C. Bacteriology of dental infection*

Most oral sepsis is of streptococcal origin. This is particularly true of dental infections. Indeed, cultures from periapical abscesses, if properly taken, usually yield a pure culture of some form of streptococcus. Both Streptococcus hemolyticus and Streptococcus viridans are encountered, but by far the greater number appear to be of the viridans variety. In taking cultures from extracted teeth, great care must be employed to prevent contaminations. The usual procedure is to sterilize the teeth and gum with iodin, and to wall off the area of operation with sterile gauze. The tooth is extracted with sterile forceps and, after extraction, the apex of the tooth is cut off

with a sterile instrument and dropped directly into a tube of culture medium. Some authors advise dropping the specimen into a tube of normal salt solution to which is added a small amount of sharp sand. The tube is then shaken to macerate the tissue on the tip of the tooth. Cultures are made from this material. The culture media that we prefer in our laboratory are blood broth and blood agar. Rosenow recommends glucose brain broth and glucose brain agar.

In recent years some interesting studies have been made on the relation to fusospirochetes to certain pulmonary infections. These organisms are found in large numbers about the teeth of patients with pyorrhea. They are difficult to cultivate on ordinary media, but can readily be demonstrated in smears by various staining methods.

### *D. Detection of dental infection*

One of the most difficult problems that both the physician and dentist have to face today is the proper handling of infected teeth. We are told that every devitalized tooth is infected, and if this is true, they are all at least a potential source of danger. Rosenow advocates the extraction of all devitalized teeth. I think, if he had his own way, no patient would ever leave the Mayo Clinic with a pulpless tooth in his head. At the other extreme is the late Dr. Abraham Jacobi, a wise and able clinician who enjoyed perfect health to the age of eighty, and who is said to have had a root abscess about every tooth he possessed. He paid no heed to the arguments of his medical and dental friends, insisting that he would retain his teeth so long as the abscesses caused him no trouble. Both of these positions are radical ones, and represent extreme points of view that very few medical men would care to take. Nearly all of us carry around a few devitalized teeth, and would prefer not to part with them, even if we do have occasional arthritic pains. Personally, however, I should be opposed to retaining teeth that showed definite signs of periapical infection, even in a healthy patient, for we can never tell how much latent harm such a focus may be storing up for such organs as the arteries, kidneys, or heart muscle.

Physicians and dentists have come to depend almost entirely on radiographic findings for the detection of dental infection. Certainly the radiograph is a most valuable aid, although its reliability depends

in large measure on the technical skill with which the x-rays are taken. The bone details should be good, and the teeth shown in their proper relation and perspective. It is preferable that two views be obtained of each tooth, and it is important that the whole mouth be included so that residual alveolar infection will not be overlooked. In interpretation of x-rays of the teeth, we must remember, however, that a negative radiograph does not always preclude dental infection, nor on the other hand does a positive x-ray necessarily mean the actual presence of bacteria about the teeth. Granulation tissue about the root of a tooth is an expression of defense on the part of the body. If the defense is good, the bacteria may be entirely destroyed and the inflammatory tissue become sterile. This phenomenon would explain why apparently infected teeth often give no trouble to the patient. The dental clinician realizes even more than the physician the limitations of radiographs in the demonstration of dental infection, and gains much information from vitality tests, percussion, sensitiveness to heat and cold, and transillumination.

### *E. Dentistry and internal medicine*

It is with internal medicine that dentistry will always be most closely allied. In this field it is particularly with infections that these two divisions of medicine meet so often on common ground. Generalized infections of obscure origin, particularly those in which streptococci are recovered from the blood stream, are not infrequently referable to periapical infection. In my experience, this type of streptococcal septicemia has usually occurred in elderly patients. Rheumatic fever is probably a streptococcal disease, but in most cases is secondary to infected tonsils or sinuses rather than to diseased teeth.

Chronic infectious arthritis is a disease which, perhaps more than any other, has brought medicine and dentistry into close and significant contact. Incidentally I may say that I know of no phase of modern hygiene that has been "put over" so successfully to the general public as the relationship between chronic rheumatism and infected teeth. In our arthritis clinic at the Cornell Dispensary, I have been amazed to find that practically every arthritic comes to the clinic fore armed with a complete set of x-rays of his teeth. Through some

channel or channels of propaganda, every man, woman, and child in the United States seems to have been taught that rheumatism is related to teeth. This of course is as it should be. I only wish that many other health measures could receive such splendid public support.

During the past three years I have been particularly interested in the etiology of chronic infectious arthritis, and some interesting studies on the bacteriology of this disease are being conducted in my laboratory at Bellevue Hospital. By utilizing new and somewhat revolutionary bacteriological methods, we have been able to cultivate streptococci from the blood and joints of a rather high percentage (62 per cent) of patients with active infectious arthritis. These streptococci, when injected into rabbits, produce in them the typical picture of polyarthritis, and the same streptococcus can be recovered from the blood and joints of the infected rabbits. Furthermore, in a number of cases, a streptococcus has been isolated from some focus of infection which is culturally and biologically identical with the streptococcus recovered from the blood or joint of the same patient. In this work, the biological relationship between these streptococci is established by means of agglutination and absorption tests. The following case will serve as a good example.

A man, aged 61, gave a history of pain and stiffness of both hips of ten years duration. Physical examination showed ankylosis of the left hip in a flexed position. The right hip also showed considerable limitation of motion, but was not ankylosed. An x-ray of the hip joints revealed marked distortion and flattening of the head of the femur, with obliteration of the inter-articular space. The right hip was affected in the same way, but to a less advanced degree. Radiographs of the teeth exposed one rather large periapical abscess. This tooth was extracted, and following its extraction, the patient developed acute pain and swelling of the left wrist. An arthroplastic operation was performed on the left hip, and cultures were made from the joint at operation. A streptococcus was recovered from these joint cultures after thirteen days of incubation. Cultures were also made from the abscessed tooth and from the blood. A streptococcus was recovered in pure culture from the root abscess and also from the bloodstream, and when these streptococci were matched by cultural and agglutina-

tion tests with the streptococcus recovered from the joint, all three strains were found to be absolutely identical. This streptococcus was injected into a rabbit with the production in the animal of a chronic arthritis, and the same streptococcus which had been originally injected was recovered from the rabbit's blood and joints.

It seems to me that studies such as these remove focal infection from the field of theory and place it, where it belongs, as one of the foundation stones of modern medicine.

In connection with arthritis, I wish to say something concerning that very large division of arthritis which is noninfectious in character. This type of arthritis is usually spoken of as degenerative, hypertrophic, or osteo-arthritis, and occurs in middle-aged and elderly patients, apparently as just one more phase of what we call "old age." Degenerative arthritis affects chiefly the fingers and the weight-bearing joints. The pathological changes are quite different from those which characterize infectious arthritis. In the latter condition the lesions are frankly inflammatory and are found in the soft tissues, especially the synovial membrane and the capsule of the joint. In degenerative arthritis it is the bone and cartilage which bear the brunt of the attack. The changes, furthermore, are not inflammatory in character, but display real degenerative qualities. The cartilage becomes fibrillated, the bone increases in density and bony outgrowths occur around the edge of the joint. A great injustice is often done these old people by some enthusiastic practitioner who removes all their dental work, and perhaps all of their teeth, with the expectation of curing the patient of degenerative arthritis. In such instances the doctor and the patient are both doomed to disappointment. The condition of the joints does not change, and the disgruntled patient is made more unhappy by the loss of his teeth. I do not know which sight fills me with more regret—to see a robust young man who has been allowed to drift into a deforming arthritis for lack of an obviously needed tonsillectomy, or to behold a fat old lady with creaky knees who has had all her teeth extracted for nothing.

While on the subject of infections, something must be said about the very important studies which have recently been made concerning the rôle of fusospirochetes in the etiology of bronchiectasis and abscess of the lung. Both of these maladies are characterized by the expecto-

ration of fetid sputum, which usually contains large numbers of fusiform bacilli and spirochetes similar in all respects to those found about the teeth in pyorrhea. Most patients who develop these conditions show signs of infection about the teeth. Furthermore the investigations of Smith and others have shown that bronchiectatic cavities and abscess of the lung can be readily produced experimentally by the intratracheal injection of these spirochetes. Strangely enough, streptococci and staphylococci alone will not produce abscesses. A mixed bacterial flora containing spirochetes seems to be necessary. Abscess of the lung usually develops after pneumonia, after some operation, particularly about the nose or throat, or after the extraction of teeth. I think the feeling among medical men is that most abscesses of the lung could be prevented by proper mouth hygiene. I recently saw a case in point at Bellevue Hospital. The patient was a young man with very severe lobar pneumonia. Pneumococcus Type II was isolated in large numbers from his sputum and also from his blood stream. In the presence of such an extensive pneumococcal septicemia the prognosis seemed hopeless, but antipneumococcus serum was administered in large doses, and much to our surprise the temperature began to drop and the patient seemed to be well on the road to convalescence. Suddenly, however, the temperature rose again and the patient began to bring up large amounts of very foul, dirty-looking sputum. The symptoms and signs of lung abscess developed rapidly, and he died in the course of two weeks. This man, like most of our Bellevue patients, had very extensive caries and pyorrhea. We remarked at the autopsy that, if he had taken care of his teeth, he would probably have survived his pneumonia and never have developed the complicating abscess.

### *F. Relation of the teeth to various other medical conditions*

Let us now consider briefly the relation of the teeth to some other medical conditions. The stomatitis of mercury poisoning, and the lead line on the gums in lead poisoning, are two striking manifestations of chemical intoxication which are often first observed by the dentist, and if recognized in time may save the patient from more serious symptoms.

In the deficiency diseases one is tempted to do considerable specu-

lation as to the rôle of vitamine deficiencies in the production of caries and pyorrhea. The gingivitis of scurvy is now known to be due to a lack of vitamine C—the so-called antiscorbutic vitamine. Typical scurvy, with gingivitis and pyorrhea, can be produced in animals and cured at will by so regulating the diet that it is either deficient or well supplied with this vitamine. In rickets and other deficiency diseases, delayed dentition is a well-recognized symptom; and there is reason to believe that a deficiency of vitamine A, the so-called fat-soluble vitamine which appears to be concerned in the production of rickets, may be also related in some way to the quality of both the deciduous and permanent teeth, and thus play a rôle in susceptibility to dental caries. Certainly the quality of the teeth seems to be related in some way to calcium and phosphorus metabolism. At the present time, most well-cared-for babies receive cod liver oil, cereals, and orange juice, that is vitamines A, B, C, and D, during the first two or three years of life, and then for some reason they are discontinued. I am beginning to wonder if it would not be well to continue this high-vitamine diet in children up to the age of eighteen, that is, until the period of growth is ended. It is quite possible that such a regime, if carried out on a large scale, would improve not only the average physique, but the average set of teeth as well. The problem of caries, however, is one of the most complicated in the whole field of pathology. Its solution will need help from the embryologist and physiologist as well as from the chemist and bacteriologist.

In the diseases of metabolism, diabetes and gout should both be mentioned. The diabetic is especially prone to infections of all kinds, and for this reason his teeth and gums should be kept in the most perfect condition. The patient with gout is predisposed to a secondary infectious arthritis, and hence should be carefully protected against all foci of infection.

As for the digestive system, time will not permit a discussion of the various infections of the mouth, but a word should be said concerning the relation of the teeth to dyspepsia. In medical clinics a good many of our dyspeptic patients, of the poorer type, are found to be completely or almost completely devoid of teeth. The bicuspids and molars have been extracted for one reason or another, and the patient has never replaced these with adequate substitutes. As a result, the

patient soon develops the habit of swallowing food without preliminary mastication and symptoms of indigestion follow.

I must remind you also that focal infections about the teeth and in the tonsils are again receiving a great deal of emphasis in the study of peptic and duodenal ulcers. Rosenow's interesting studies in this field did not meet with very enthusiastic support at the time they were promulgated fifteen years ago. Recent studies, however, by Haden and others tend to confirm Rosenow's theory that gastric and duodenal ulcers are streptococcal infections secondary to some primary focus, usually in the tonsils or teeth.

Focal infections probably also play an important part in the etiology of infections of the gall-bladder and vermiform appendix.

Diseases of the heart and kidney cause more deaths than any other of man's ailments. Our wards at Bellevue Hospital are always filled with these conditions. In making my rounds, I often wonder how much of the tissue damage is due to the wear and tear of life, and how much to focal infection. The recent studies of Longcope show quite clearly that one form of kidney disease, the so-called glomerular nephritis, is dependent in a large number of cases on the presence of hemolytic streptococci in the pharynx or tonsils. Haden in his book on dental infection describes several cases of pyelitis and pyelonephritis which appear to be referable to periapical abscesses. The dependence of certain types of myocarditis on focal infection is well known, and the relationship between bacterial endocarditis and foci of infection is too well recognized to command more than passing mention. I recently saw a case of bacterial endocarditis in a young man of thirty with a history of one attack of rheumatic fever in childhood which had left him with a mild chronic valvular disease. He had taken very poor care of his teeth, so much so that his dentist had sent him several urgent messages to come in for treatment. In such a case it was hard to resist the conclusion that the streptococcal infection on his heart valve was closely related to his multiple root abscesses.

In the field of endocrinology considerable stress has been placed upon the relationship between focal infection and hyperthyroidism. I have personally seen several cases of Graves' disease in young women that were much benefited by a tonsillectomy or by the removal of some infected teeth. Haden reports an interesting case of

subacute thyroiditis in a woman of 38, whose thyroid was swollen, tender, and indurated. The blood count was 14,000 and the basal metabolic rate was 26 per cent. She had a daily rise in temperature, had lost 30 pounds, and was developing the other symptoms of a hyperthyroid state. There were eleven pulpless teeth and marked pyorrhea. Thyroidectomy did not give permanent relief, but, following the extraction of the pulpless teeth, there was a gradual return to complete health.

This cursory review of focal infection in relation to internal medicine is sufficient to indicate the tremendous importance of focal infection in the field of medicine proper. I recently heard a prominent practitioner remark that in his experience, about nine tenths of the modern practice of medicine was devoted to searching for foci of infection.

### *G. Relation of dentistry to other specialties*

I have devoted considerable space to the relation of dentistry to medicine, because medicine happens to be the field in which I am personally most interested. However, it would be unfair for me to close this address without making some reference to the important bearing of dentistry on some of the other medical specialties.

Neurology is becoming more and more a study of infections of the nervous system. The commoner infections of the nervous system, such as meningitis, encephalitis, and poliomyelitis appear to be secondary to primary catarrhal infections in the nose and throat. One of the commonest conditions encountered in the neurological field is neuritis, and certainly it is one of the most stubborn conditions to overcome. A great deal is said in the textbooks about trauma, alcohol, and metallic poisons as factors in the causation of neuritis, but not nearly enough emphasis is placed on focal infections as responsible for this condition. Furthermore, I know of no disease, not even arthritis, which can so frequently be referred to an abscessed tooth. The dependence of a facial neuralgia on impacted or infected teeth is perhaps more generally recognized by dentists than by medical men. The prevalent view of neuralgia among neurologists is that neuralgic pain is practically always due to some kind of mechanical pressure. This pressure may be only slight and for this reason it is obvious that neuralgia of the face will often be referable to pressure

on the dental nerve at some point which may be quite difficult to determine by examination of the teeth.

What shall we say about the relationship of dental infection to the psychoses? Cotton and others have laid a great deal of emphasis, perhaps too much, on the importance of dental infection in the etiology of various forms of insanity, but even assuming that this theory has been overstressed, we must all agree that dental hygiene is an important part of the modern treatment of the insane patient.

In respect to pediatrics, we are concerned chiefly with preventive dentistry. Perhaps the most important phase of this problem is the determination of adequate vitamine supply in the child's diet. Next in importance I would place orthodontia. The orthodontist has come to play an active part in the lives of children with "crooked" teeth. Whether these irregularities are hereditary, nutritional, or mechanical, they must be corrected as far as possible not only for aesthetic reasons, but for the better preservation of the teeth themselves. It is perhaps only fair to say that there is a feeling among medical men that orthodontia is being overplayed at the present time. The actual discomfort which many children undergo because of these orthodontic appliances is perhaps not of so much moment as the inferiority complex which many of them develop from the consciousness that the appliance is always in evidence.

In respect to surgery, dentistry comes into the closest possible contact with stomatology. I do not propose at this time to go into the question of the proper fields of dentistry and stomatology. Disregarding the changes the future may bring, we now have oral surgeons in all of our large cities, men specially qualified in the operative technic of mouth surgery and with a practical knowledge of dentistry. These men are valuable assistants to the general practitioner of medicine, and no doubt serve a useful function to dentists as well. The laryngologist comes into contact with the dentist chiefly in the field of sinus work. The purulent discharge which comes from an infected antrum is usually odorless, and yields on culture streptococcus, staphylococcus and some of the other common pathogens. Occasionally however, the discharge is foul, and in such cases fusospirochetes are present in large numbers. It is this type of sinus infection that follows the extension of a periapical abscess through the sinus

wall, and permanent relief will come only when the offending tooth has been extracted.

When we come to ophthalmology, we naturally think first of rheumatic iritis. Focal infection plays a most important part in the etiology of recurrent iritis and uveitis. The connection between iritis and rheumatism has long been recognized, but it was not until the recognition of the part played by focal infection in both of these conditions that a satisfactory therapy was worked out.

At this point I would like to say a word about local anesthesia. From time to time, one hears of fatal accidents in the domain of general or specialized surgery following the use of local anesthesia. These tragedies are almost unheard-of in dentistry, the reason being of course that in surgery cocaine or mixtures of cocaine and novocaine are frequently employed, while dentists adhere strictly to novocaine.

From what has already been said, it must be obvious to you all that there is almost no limit to the field of dental disease and dental infection in the domain of medicine and surgery. It is fortunate indeed that medical educators are becoming aware of this fact, and that more and more attention is being devoted to dentistry and stomatology in the planning of medical curricula. At the present time it seems to me that we are far from a satisfactory situation. For example, in one year a patient may spend many hours and much money with a dentist who puts in several bridges and crowns for him. The next year he develops some rheumatism and his physician may order all of this elaborate dental work removed. Can we wonder if the layman is a little annoyed by such a procedure, especially if his rheumatism is not relieved after his beautiful dental work has been destroyed? Situations of this kind can only be remedied by very close coöperation between the two professions. Let us hope that the time of such close coöperation is not far distant.

## II. THE RELATION OF DENTISTRY TO MEDICINE

*Leroy M. S. Miner, D.M.D., M.D., F.A.C.S., F.A.C.D., Boston, Mass.*

The relation of dentistry to medicine has aroused recurrent interest and provoked unlimited discussion, especially since the war. The importance of the subject demands the best efforts of every one sincerely interested in health matters to improve a situation that is,

in many respects, unfortunate. The correlation of medicine and dentistry is a public necessity in the interests of the health of the nation. A monarch of ancient times once said: "The health of the people is the supreme law." On this declaration rests a deeply rooted instinct for the preservation of the human race and the foundation of all moral, intellectual, and physical progress of mankind. Higher levels of health and attainments in physical perfection are dependent upon the intelligent application of such knowledge as we possess and ardent pursuit of new knowledge. But even in nations with culture and learning progress is slow. Prejudices, apathy, jealousies of different groups, interfere with and retard the absorption by the masses of advancements in the laws of health.

A great deal of publicity has been given these last few years to the teeth as a causative factor in various systemic diseases. But the importance of the teeth in the body economy is by no means a modern idea. John Hunter, Surgeon Extraordinary to the King of England, whose fame rests not only on his ability as a surgeon but also upon his achievements as a scientist, published, as his first important work, "The Natural History of the Human Teeth." The second edition, dated 1778, contained a practical treatise on the diseases of the teeth, intended as a supplement to the natural history of those parts. In the introduction Hunter wrote:

"The importance of the teeth is such that they deserve our utmost attention, as well with respect to the preservation of them when in a healthy state, as to the methods of curing them when diseased. They require this attention, not only for the preservation of themselves as instruments useful to the body, but also on account of other parts with which they are connected; for diseases of the teeth are apt to produce diseases in the neighboring parts, frequently of very serious consequences. One might at first imagine that the diseases of the teeth must be very simple and like those which take place everywhere else in the bony parts of our body, but experience shows the contrary. The teeth being singular in their structure, have diseases peculiar to themselves. These diseases, considered abstractedly, are indeed very simple, but by the relations which the teeth bear to the body in general and to the parts with which they are immediately connected, they become extremely complicated."

The significance of these simple but fundamental truths, so tersely expressed more than 150 years ago by a man of accepted standing in medicine and science, was not appreciated; the possibilities for the development of dental pathology in its relation to disease of the organism as a whole were unfortunately ignored or overlooked. After almost a hundred years, during which period no progress whatever had been made in the care of the mouth, or more exactly the teeth, a few doctors of medicine, in at least two sections of this country, tried, with the help of forward looking dentists, to establish dentistry on a firm educational basis by having it included in the curriculum of the medical school. The immediate and later results of these efforts are well known to you. The dental school, as a separate educational unit, is one of the outstanding results of what has been called "a historic rebuff."

From the establishment of the first dental schools up to the World War period, dental education concerned itself chiefly with mechanics and aesthetics, and paid no attention to the "relations which the teeth bear to the body in general and to the parts with which they are immediately connected," which Hunter had pointed out. But refinement of mechanical technique developed new problems in pathology, and the subject of systemic disease resulting from disease in the mouth began to attract attention toward the end of this period. Since the World War the dental profession has been acutely conscious of its responsibility in matters pertaining to the health of the individual and the public health. With this new development has come the recognition, by those who are honestly interested in the progress of dentistry, that better and broader training is imperative if the dentist is adequately to cope with his new problems. And so again there is developing a movement of some proportions to weave dentistry into the fabric of medicine. Hunter's efforts to convince the profession of his day of the importance of the teeth, and of the relations they bear to the body in general, were fruitless. The second effort a hundred years later was equally barren. The outcome of the third effort now being made, at a period when laboratory and clinical research has demonstrated the truth of Hunter's statements, will depend upon the breadth of vision of the leaders in dental education, upon their ability to command the active coöperation of leaders in medical

education, and upon their ability to attract the financial support that will make dreams realities.

From this outline of the development of dentistry in its relation to the healing art, it seems evident that progress has been painfully slow. An attempt to analyze the reasons for this should be of service in avoiding past mistakes and in assuring greater accomplishments for health in the future. But first an understanding of the word progress may be of some importance. Robert Millikan, in a lecture on "Evolution in Science and Religion," has given us an extremely satisfactory definition. "Progress," he says, "is an increasing control over environment." If we ask ourselves, "Has dentistry progressed in this sense?," most of us will admit dissatisfaction with results. Progress has not been altogether brilliant. Why? *First*, perhaps, because there has been no fundamental philosophy underlying dentistry. It has been almost a case of "We don't know where we're going, but we're on our way." When dentistry has clarified its problem, when it has a well defined conception of what its function really is, when its objectives are biologically basic, then may we expect a rapidly increasing control over environment. *Second*, apathy of medical men toward dental matters, and the traditional prejudices between dentistry and medicine, have interfered with the accumulation of knowledge in problems of mutual interest. These traditional prejudices have no justification on any reasonable ground, but their causes are not difficult to see. Dentistry and medicine have, in the past, had very little in common. There have been no common objectives, therefore no common interests. Dentistry has concerned itself largely with mechanics, repair of defective parts, replacement of lost parts, with no thought whatever of any health relationships. *Mechanics* has been the chief objective, mechanical skill the major accomplishment. Do not think I am trying to belittle the attainment of skills in dentistry. I am not. I am expressing my opinion that the emphasis has not been altogether where it belongs. Even today, when we are attempting in some of our dental schools to place values in their proper places, mechanics frequently crowds out other considerations.

An experience with a group of students only a few days ago will illustrate my meaning. A thin, anaemic-looking girl of 18 was being

examined with a view to determining what should be done for her mouth. The gums were very red, several broken-down roots were present, many teeth were carious, and several teeth were missing. After the student group had examined the case, upon request one of the students expressed his opinion as to how we should proceed. Boiled down, he advised treatment of gums, extraction of roots, filling of numerous cavities, and making of plates—entirely correct procedures from the mechanical viewpoint. But nothing was said about any effort to find out the patient's physical history; no curiosity regarding the reason for the multiple caries, with the view of preventing future trouble, was evident. No question was raised whether the condition of her mouth was the cause or effect of her obvious physical disability. In other words, there was no interest in the fundamental problem—the *health* of the girl and the relation of her dental physical condition. Until this is the primary interest, in every-day practice, of a majority of the dental profession, dentistry cannot hope to be considered a specialty in medicine, nor can dentistry expect to arouse any enthusiasm in the medical man for its activities. All this cannot be accomplished until dental education has readjusted its curriculum and eliminated its deficiencies in some of its fundamental medical aspects. But achievement in this direction alone will not bridge the gap between the two professions.

Dentistry, it is true, is handicapped through a lack of knowledge of the fundamental principles of medicine and of the body in normal function and disfunction, but medicine is in like position through ignorance of dental pathology and practice in relation to health and disease. Each lacks, therefore, the necessary perspective which might be less noticeable if there were more educational coöperation. The medical school has on its side deficiencies in dental matters, and the desire to eliminate them must come through inspired leaders in dentistry convincing medical faculties of the need of having the medical man appreciate the fact that "the mouth means more in the economy of the organism than a place to put a thermometer." At a meeting of the American Association of Dental Schools, last March, Dean Seccombe, of Toronto University, read a paper urging the need of some dental training for medical students. He pointed out that there are many physicians who entirely ignore the possibility that

dental conditions affect other parts of the body, and who advise the extraction of teeth too freely and without sufficient dental knowledge to permit of a correct diagnosis.

As a result of the obvious need upon which Dean Seccombe focussed attention, that refuge in a time of storm, *a committee*, was appointed to gather information and to stimulate interest and action. Through the coöperation of the Carnegie Foundation for the Advancement of Teaching, facts have been compiled regarding existing instruction in medical schools on aspects of dentistry. Of eighty-one schools, only fourteen give required courses or special runs of lectures on oral hygiene, clinical dentistry, or oral surgery. Sixty-seven do not give formal attention to dentistry.[2] The required courses in the fourteen schools are lecture courses averaging only about eight hours. In no instance is the formal attention to dentistry in these fourteen schools equal in scope or quality to that given to conventional medical specialties. The number of medical schools giving formal instructon in dental subjects in 1924–25 was nine—five less than at present.

The report of a Committee on Dental Education, made at the National Conference of Canadian Universities held last year, was concerned almost entirely with the subject of dental instruction for medical students and practitioners. The Committee concluded that medical students should receive such instruction in dentistry as will enable them, upon graduation, to understandingly coöperate with dental practitioners in cases where the patient's teeth are involved. It made two definite recommendations: *first*, the establishment of a course of instruction in dentistry for medical students, comprising about ten lecture hours, supplemented by necessary clinical demonstration. Subjects for consideration included "The etiology of dental diseases," "Dental diagnosis," "Radiography and x-ray interpretation," "Preventive dentistry," including "Oral hygiene and diet." *Second*, a proposal that the Faculties of Dentistry coöperate with the Canadian Medical Association and its branches in the preparation of an illustrated Bulletin upon dentistry for distribution to Canadian practitioners of medicine. When general university officers, and faculties of all departments including the medical school, are convinced that the dental school is an important member of the university

[2] There are now 81 medical schools in the United States, of which six are proprietary.

group and that its educational standards are on a plane as high as any, then dentistry will make more notable contributions to the welfare of mankind than has yet been possible. But this recognition can come only by deserving it. To deserve it is dentistry's problem, the solution of which will not come by independent action nor by a desire to be independent, but through active coöperation and help from all university groups in the educational field, and the professional groups in practice. Much can be learned from the graduate schools in arts and science, education, business, and medicine. I find most of these faculties eager to help improve dental standards.

As Hunter suggested, the relations which the teeth bear to the body in general are extremely complicated. It is not my purpose to go into the details of this subject, but a few general statements may serve to emphasize both the complexity of the problem and the need for assistance from every available source.

The subject of teeth as an etiologic factor in serious systemic disturbances, through dental focal infection, has received concentrated attention for some years, and has served to impress upon the medical and other groups the fact that dentists are, or at least should be, more than good mechanics. And it accordingly has served an extremely useful purpose. But this may be the least important part of the whole subject. The effect that varying conditions of health have on the hard and soft tissues of the mouth, and changes that result therefrom, are subjects of vastly greater significance. In 1918 I called attention to the fact that the tissues of the mouth were extremely sensitive to changes in the rest of the body, and that the mouth was a barometer of the patient's health. This idea is not a new one. About 150 years ago John Hunter wrote: "Whichever of the connected parts be originally diseased the teeth are quickly the greatest sufferers. None of these parts can be distempered without communicating to the teeth such morbid effects as tend to the destruction of them." In these thoughts is locked up the solution of the problem of dental caries, which is one of the major puzzles confronting us, the settling of which will be of unlimited benefit to mankind.

There is another phase of dentistry's responsibility which has been actively pursued these last few years also. I refer to the subject of prevention. The main service of medicine has been the treatment

of disease and the relief of suffering. Disease is the commanding interest. Many of the dental profession have seen the importance of the opposite phase, and have been inspired with the idea that the present day obligation is to develop and maintain *health* in the mouth, and as a secondary effect, *health* in the rest of the body. President Lowell, in his annual report recently published, says: "The physician and surgeon are commonly regarded as men who minister to people suffering from severe and otherwise fatal maladies, whereas the greatest function of the dentist is the prevention of disease, a fact well known to medical men but as yet little understood by the public." But the prevention of disease requires a knowledge of its cause. The attainment of this knowledge demands the talents of all groups interested in the biological sciences.

From what has preceded, are we not warranted in saying that dentistry should replace the thought that its work is of second-rate importance with the conviction that it is doing a noble work for mankind? Should not dentistry slough off its professional provincialisms, and step out into the world of scientific endeavor? Then and only then will medicine and dentistry come together on terms of mutual respect. The ability to accomplish this rests with the achievements of dental education in the next ten years.

### III. DISCUSSION

*Henry W. Gillett, D.M.D., F.A.C.D.* (*New York City*): It is superfluous to say that all of us who have thought of the matters presented by Dr. Cecil and Dr. Miner agree in the main with what they have said so well. I want to emphasize two points that are not frequently spoken of in dental meetings. I am glad to have opportunity to speak of them in the presence of so many medical men.

One of the important factors in mouth pathology is the condition around the teeth in well advanced stages of pyorrhea, where there is not only the seepage of considerable quantities of pus into the digestive tract and absorption of poisonous material into inflamed tissue lying immediately adjacent, but also direct forcing of accumulated pus and foul material from pyorrhea pockets into the blood and lymph streams, by reason of the pestle-like action of loosened teeth resting in partially destroyed bony sockets surrounded with vascular tissues supplied with open lymphatic channels.

The second point I want to speak of, which seems to pass without much

consideration, even among dentists, is the fact that in malocclusion, to which Dr. Cecil referred, there is direct relation between the malposition of the teeth, with the resultant deformities of the maxillae, and the adjacent bones and inadequate air passages, which necessarily stand in a direct etiologic relation to disease of the respiratory tract.

I regard as sound Dr. Cecil's reference to a probable relation between foul mouths and lung abscesses. It would be just as logical to have a sewer trap inserted in the inhaler when administering an anesthetic, in a position to insure constant dripping of fluid from it into the fauces, and to leave it connected during the period of conscious control of the throat muscles, as it is to leave in a similar relation uncared-for mouths in the condition in which they are usually found.

*W. B. Dunning, D.D.S., F.A.C.D.* (*New York City*): When, in informally introducing Dr. Cecil, the President began his story in regard to the telephone message to the South Pole, it occurred to me that the moral was to be, or should have been, the regrettable distance between two well meaning and intelligent bodies of professional men, the so-called medical and the so-called dental profession. It seems to me very unfortunate to keep speaking of two professions, particularly in the light of the papers we have had this evening, which gave such impressive evidence of the intricacy and the intimacy of our problems. We must get out of that habit of speaking and of thinking. It is a fundamental mistake to keep alive the idea of separation between our activities.

I have said before on similar occasions that in professional education the best we can do at present, in all likelihood, is to have our dental schools and our medical schools as separate entities in close affiliation under university management. Probably we cannot do better than that, because there is so much of a special nature in the technical equipment of the dentist of to-day that such a plan of education is necessary to provide the unique training and the volume of special knowledge that a dental operator must have always at his finger tips. Nevertheless, he must have also the broadest foundation that is practicable in the biological subjects, with the mental habit of seeing the whole body, with his own field as a glorified section of it. In practice he should always be in close contact with the general medical practitioner, and by the same token the general medical practitioner should always be in close contact with the dental specialist.

I do not even like the idea of our being considered twins. I think the simile of the Siamese twins would be better, held together by a bond of union which would threaten the life of either if it were separated.

These are glittering generalities, but I sincerely hope that we will start a good discussion tonight, bringing out matters that will be wholesome for all of us. I think that Dean Miner made a courageous remark and a true one in speaking of dental provincialism. There is much about our education at present that is narrow and insufficient, but at the same time we must not be carried away with the age-old fetish that the conventional M.D. degree is the whole answer. Between these two extremes is room for our wisdom, and I hope we will reach some of it tonight in the course of this discussion.

*R. W. Waddell, D.D.S.* (*New York City*): Please permit me to express my gratitude for the privilege of hearing these two papers. One of the reasons why the dental and medical professions have lacked coöperation is that the dentist, in solving his problem with the knowledge in hand in years past, has not found it necessary to apply to the physician. In making a diagnosis the patient did not even need the dentist. As a rule, the patient could tell you whether a tooth was carious or not; it was perfectly obvious. Then all the dentist needed was to look in "*Items of Interest*," and find out how Dr. Gillett there says to do it.

Every dentist is familiar with the picture of the "perfectly normal, healthy child" with many carious teeth. The parents believe the child is in perfect health and bring him to the dentist to have his teeth filled, which the dentist proceeds to do. After long, laborious effort and great patience, the treatment is completed. Six months later the patient comes back and we start all over again. Nothing has been done towards solving the problem in the manner suggested by Dr. Miner. With our present enlightenment, we are not competent to solve that problem. Realizing this, we apply to the physician. It has been stated that carious teeth are the result of a deficiency of calcium. Is it not possible to learn whether this is true, if a very large number of these cases could be sent to the pathologist; and may we not learn to do something other than filling teeth?

*John Oppie McCall, A.B., D.D.S., F.A.C.D., F.A.A.P.* (*New York City*): While listening to these papers, which I have enjoyed intensely, I was struck by the general character of each. If Dr. Cecil had not been introduced as a physician and Dr. Miner as a dentist, I think it would not have been putting too much of a strain on our credulity if we had been told that the first paper was written by a dentist and the second by a medical man.

In thinking over the contents of these papers, I have also been impressed

by the fact that a very definite problem has been raised here, although one not quite voiced in the papers, and that is the fields of medicine and dentistry as regards the mouth. In dentistry, and particularly in dental education in late years, we have been thinking that the dentist should be given more medical training, should be made more of a physician. We have also been told this evening that the physician should be given more dental training. I think that it is undoubtedly true that each group will benefit by receiving a considerable amount of instruction along these lines. But I think it is also true that there must continue to be a definite field for each profession, and that we will get our best results, in terms of health for our patients, both in the mouth and other parts of the body, by each profession doing its best work in its own field. For instance, a patient is under medical care and is supposed by the physician to be suffering from a focal infectious disease. He is sent to the dentist for an examination of the mouth, which will, of course, include radiographic examination. The message is sent rather directly that the presence of foci of infection is suspected or, at least, information is desired as to whether any are present. Under these circumstances the dentist makes his examination, and reports what he believes to be the situation. No one, I believe, feels that it is necessary or desirable to train the physician to make this oral examination and diagnosis. Now suppose, on the other hand, that the patient comes to the dentist first, and has in his mouth teeth which the dentist believes may be, or probably are, infected. What is he to do about it? I am not at all sure that, in a considerable number of cases, the dentist is in a position, even if he has had a full medical course, to say that such teeth should be extracted or should be retained. I believe that, in a great many of these cases, it is necessary for him to make a report to the physician, and ask his advice as to whether the presence of suspicious teeth in the mouth may be regarded as detrimental to the patient's health. I don't believe that is a question the dentist can always settle for himself, or can be trained to settle in the routine education of dentists.

Again, in the field in which I have been especially interested, periodontia, I have been impressed more and more as time goes on with the belief that an important part of the etiology of disease of the supporting tissues around the teeth is to be traced to a systemic shortcoming. I am not at all sure that the dentist, even if given a medical course, is going to be able to find out what that shortcoming is. I believe he must go to the physician for that information. Up to the present time, in the cases in which I have followed this procedure, however, I have not always received the help I hoped to get. I believe that before this information is forthcoming, the

physician or the research worker will have to study the things which lead up to periodontoclasia in a way which apparently has not yet been done. In other words, I believe that we must continue to function as branches of one great healing art, but without any very definite attempt to merge the two into one, with, of course, an increasing study of the problems of each on the part of the other.

*Alfred Owre, A.B., D.M.D., M.D., Sc.D., F.A.C.D. (New York City)*: I wish to restate now what I have felt for a long time, that dentistry should be considered a specialty in medicine and that we are working toward that end. We are not there, but we are on the way. A few days ago I sent a communication to the deans of the medical schools in this country and Canada, with an extract of five particulars from a speech by Dean Winternitz of the Yale University Medical School, made a few weeks ago at Columbia University. In this he called attention to the same thing, that dentistry should be regarded as a specialty of medicine. I asked these deans to give me their views on this, because I realize that dentistry is at the cross roads. Two speakers tonight called attention to the fact that we cannot go on with our mechanics alone. Science has now contributed so much, has challenged our position so keenly, that we must be able to function with medicine in the sense that we can define what is going on in the mouth.

These inquiries were made about three weeks ago. To 70 of them as sent out, I have had 35 replies; not one of them disagrees with the thesis that dentistry should be a specialty in medicine.[3] A great many of them call attention to the fact that there are certain difficulties in the way of accomplishing this soon; but they also expand upon this and utter the hope that it is on the way, and cite it as our future goal. I hope that some time I may have the opportunity to present these views more in detail; I have permission to quote most of these writers. I agree that it cannot be done at the present time, that is, not at this minute; but the sympathetic attitude of these letters shows that there has been a certain amount of thought and of looking into this problem on the part of medicine. They are proud to refer to the fact that they have established dental services in their schools and in their hospitals. "What are you doing?" a great many of these men ask me directly when I meet them in medical meetings, "so that we can consummate this plan? Do you expect us to take over all of your mechanics and give you university credit for that? If so, that cannot be done."

[3] Dr. Miner's comment on the lack of required courses on dental subjects in the United States medical schools appears on page 155.—[*Ed.*]

So it seems to me that we have reached the cross-roads. We must make some kind of scientific readjustment of the present dental curriculum; you can rely upon the fact that medicine also is readjusting her affairs most energetically. Within two or three years two of the leading medical schools in this country have cut their curricula in the first two years in order to get rid of a lot of things they didn't need. That was done in one instance to accommodate dentistry, so that students in both schools could take the same thing the first two years. That I think is progress. It seems to me that we shall not have to wait very many years before we shall consummate this and be one, as Dr. Dunning remarked. That was a very appropriate remark of Dr. Dunning's—that he did not want to think of two professions. We are one—dentistry is a specialty.

There are various departments that make up medicine. Medical men who do not know enough about dentistry probably do not pay very much more attention to some of the other specialties. Medical committees are now investigating these things. We now have reports to show that 70 per cent of the medical graduates specialize at the time they graduate. The Chairman of the committee who made this report told me a few days ago that we must readjust the whole business of teaching the specialties and have them all on the same plane. Now we are coming down to a point where we can have a common degree. It is an evolution, of course. Do I hope to see it? Certainly, I hope to see it, but it may not come in one decade; it may take a little longer. We are going toward that goal; that is certain. It cannot be any other way. I am reminded now of the remarks made by President Butler on two occasions when he spoke at the one hundred and seventy-fifth anniversary of Columbia University. He pointed out with genuine satisfaction the scientific adjustment of dentistry in medicine as we have it at the Medical Center.

I want to call attention to another thing, that is, that dentistry has made some response to this challenge. In 1908 some of the university schools (and dentistry belongs in the universities) felt acutely that we were not meeting the challenge of science and medicine, so we organized the Dental Faculties Association of American Universities. It was done in that center of learning—Boston. What was our object? It was this very thing, which was begun quite early in England. When Dr. Hunter's challenge was made in 1911 we were prepared for it on this side of the water. At that time there was a gap of 1500 hours between the biological preparation for dentistry and medicine. One of the first steps that we took was to reduce that year by year. It was tremendously difficult, because we had so much political opposition. That has been one of the faults of dentistry—that vicious political organization which has been operating against this

thing continually. It is still doing it, but we are going to win out. We have the leading universities with us.

*Oscar Carrabine, D.D.S. (New York City)*: Dr. Owre has said a great many things that were in my mind, but I feel that the most important po nt for us to decide is, where does dentistry end and medicine begin? We are supposed to give anesthetics, both general and local, to diagnose tumors, and to recognize syphilis. I feel that many diseases of the mouth, especially pyorrhea, are systemic diseases. The two professions are becoming so closely related that, to my mind, in time there will be only one solution and that is the M.D. and D.D.S degrees for each graduate.

*Arthur E. Neergaard, M.D. (New York City)*: I rise reluctantly to speak, but I feel that the best way in which I can show my appreciation of the privilege which has been accorded to me in being present this evening is to say a few words from the standpoint of the general medical practitioner, no matter how inadequate they may be. I hesitate to open my mouth at all in the presence of so many oral experts. I am reminded of the story that President Hadley used to tell of the man who went to the morgue in search of the body of a missing relation, and, having almost finished his identification of the body, was about to remove it when suddenly the jaw of the corpse dropped and displayed beautiful false teeth. The relative for whom he was searching, he knew, still had his own, so he disclaimed the body and left the morgue. Whereupon the Irish attendant turned to the corpse, shook his head at it sadly, and said: "If you had only kept your mouth shut, you would have got a dacent burial."

Our relation to dentistry falls along two lines: one is the association which I have with you gentlemen through the medium of private practice, and the other is the experience in hospital practice. I wish to say that in private practice when I have sent cases to you gentlemen (many of whom I know by correspondence and by telephone where I have not had the pleasure of meeting them face to face), I have always received the greatest coöperation. I say it to my shame that the gentleman on my left (McCall) is quite correct —that I much more often get help from you when I send cases to you for focal infection than you get from me when patients come into my office and say they have just been to their dentist, and he says there is something wrong with them constitutionally because their teeth are wrong, and that I am to find it. When I have taken their blood pressure and found it normal, and their blood count and found it normal, and find nothing abnormal on examination, and say I am unable to tell what is wrong with their

calcium metabolism and why they have pyorrhea, I find I am so often weighed in the balances and found wanting.

The second phase, as I said, is the hospital practice. When I was an interne, dentistry played no part in the hospital. We never saw a dentist within its doors. Then, owing to the efforts of friends like Dr. Tracy, they began to have chairs in the O.P.D., where teeth were extracted and things done for children; and gradually that has been extended until now I should not consider my service complete if I did not have the dental help I now receive. On the charts in my service, you will find a dental section on which is recorded the dental condition of the patient, and from these we get the greatest help. I remember an incident when this was first being put into effect. I came into the wards with one of the older "Attendings" one day when it was fully occupied with dental hygienists, and all these young ladies in white were bending over the patients with paper napkins and funny looking nutpicks and things, working at their mouths under the supervision of an instructor. This older "Attending," who was not familiar with the new regime that was being instituted, said: "What is all this?" as the instructor herded these young ladies out of the ward. "Oh, that, sir," said one of the wags on the ward, "is what De Quincey wrote about some time ago: 'The Flight of the Tartar Tribe.'"

So we welcome the tartar experts, and we welcome the gentlemen who come to us and help us with our oral and dental problems. We accept their challenge that there is a great deal that medicine does not know about the mouth, and a great deal that we want to learn in order to help in the common problem that meets us all—that is, the mechanical problem of the patient's mouth—and all the other problems, which have been so ably presented in these papers, in the correlation of the patient's mouth and the patient's health.

*W. D. Tracy, D.D.S., F.A.C.D.* (*New York City*): Dr. Neergaard's friendly remarks about the work of the Dental Service of the Presbyterian Hospital give me courage to say a few words. I have enjoyed a very pleasant relation at the Hospital, but will say to you that it was not an easy task to go into an old conservative institution and introduce a new idea and a new ideal. I have found great satisfaction in the coöperation we have had, and in the friendly spirit that has existed between the physicians and the dentists on our staff. If you will pardon a personal allusion, I would like to tell you that I went into a dental office when I was thirteen years old and have been in one ever since. I somehow think I don't know anything but dentistry, and I very frankly realize how little I know about it. I

have seen dentistry grow in usefulness and importance to a wonderful degree. As I look down the vista of the years, I can see how much more important it is going to be, and I am experiencing a keen satisfaction in all the events that are taking place to-day. I enjoy witnessing the ferment that is now constantly active in dental educational circles, and also in medical education. Both ferments are working toward the same thing, namely, a better understanding and greater achievement.

One reason why I have kept in the background up at the Presbyterian (I hope Dr. Neergaard realizes that I have tried to do so) is this: I can recall, when I graduated from the University of Pennsylvania many years ago, that Horatio C. Wood (I have forgotten his title), speaking to a group of medical and dental men, referred to the dental students. He said: "Now you young men have put in your three years here and you are going to graduate, and it is a regrettable thing that you have to leave our institution with the badge of partial culture pinned upon you." I was so irritated I could hardly stand it. I thought: "Here we have put in three years of intensive work in dentistry and we have passed the requirements, we have earned our degree which we are going to receive in a few days, and still this wonderful man tells us we are leaving our university with a 'badge of partial culture pinned upon us.'" Well, for many years that rankled in my youthful bosom, but ultimately I saw just what he meant. We *were* turned out into the world with a lack of professional culture. We hadn't gone the whole figure; we had not been trained in the biological sciences, and we did not know the fundamentals that were essential for our best work and to enable us to give our patients understanding and skillful service.

So I think the professor was right when he said we were to receive a badge of partial culture. I think we are working out of that, however, and in time, with a better fundamental education, the dentist, be he what he may —medical man, stomatologist, or dentist—is going to get a better education and be in a better position to serve the public. A medical friend who left just a few minutes ago asked me about dental research. I said: "I think there is more research going on in dentistry to-day than there has ever been, but we have so many abstruse problems that we must have the help of the medical fraternity to aid us in working them out. We are interested in dietetics, and in many phases of nutrition and systemic troubles which have a definite bearing on the welfare and integrity of the teeth.

I have been very much interested and enlightened by the two essays of this evening, and I think this is a memorable occasion. I wish to pay my personal tribute to both of our essayists.

*Walter P. Anderton, B.A., M.D.* (*New York City*): I want to take this opportunity of expressing my appreciation of the invitation to come here tonight, and to suggest that the relation between medicine and dentistry is very much helped and cemented by such gatherings as this. The papers this evening have been remarkable for their scientific and philosophic inclusiveness. They have covered the subject of dentistry and medicine in their relation to one another in regard to injuries, to inflammations, the chemical and bacteriological standpoints, where they have common grounds.

We have heard of the necessity for education of medical men more firmly in dentistry, and more medicine for the dentists. I think we have considerable in common between the two branches of this great profession. We have the background of ethics which is very much in common, and we also have the danger of overspecialization. Medicine has a tendency to overspecialize, and certainly dentistry has too. I believe also that one great common background of good for the whole of mankind is the ideal of both professions.

*Harold J. Leonard, B.A., D.D.S.* (*New York City*): Dentistry or dental education has been greatly torn in the last two or three years or more by the question whether dentistry should in fact become a specialty in medicine, or whether it is to the advantage of dentistry to remain closely affiliated but still separate. It seems to me that this problem is going to settle itself in the next few years by the data which we will get, which we are almost on the point of having at present, namely, the systemic causes of the common dental diseases—dental caries, periodontoclasia, orthodontic irregularities, erosion, absorption of bone under dentures, and other conditions. These conditions are being scientifically attacked, and already there are promises here and there of solutions. When the time comes that we are able to tell our patients that their susceptibility to these dental diseases is due to certain systemic conditions, and we know what these certain systemic conditions are, or are able to find out what they are in any given case—then we will be able to diagnose and prescribe medically. When that time comes, it seems to me we will naturally merge into medicine. Until that time, a medical degree—the license to make a proper physical examination or prescribe medically—is unnecessary and of very little use to the dentist. But when that time comes, it is going to be necessary for him to be medically trained and licensed.

*Francis Carter Wood, B.S., M.D., Sc.D.* (*New York City*): My own special interest is far from dentistry, as some of you know. But in connection

with this discussion about the approach of the two professions to each other, I have noticed in the last four or five years an extraordinary change in the attitude of dentists toward certain mouth lesions. I now receive from men I know, especially my good host here, Dr. Bourne, a large number of patients with either real malignant lesions of the mouth in the early stages or precancerous lesions, or even inflammatory conditions which can be effectively treated from a general standpoint. I also see patients, who have been terrified by surgeons with the threat that they will have tongues removed and things of that sort, who have chronic inflammatory lesions which the dentist recognizes owing to his familiarity with the conditions of the mouth. I have been able to save these patients' lives by very simple prescriptions and mouth washes, and a little sympathy over the fact that they would not have to have an extensive surgical operation to remove the simple inflammatory process. That is a great change; it has come within the last few years, and illustrates the approximation of the two professions in a very graphic way.

Dr. Cecil spoke of the relation of certain general conditions, rickets and others, to calcium metabolism and the condition of the teeth. I have one observation to make which has interested me a great deal, and which I think should be extended. It happened that two boys, relatives of mine who were about the age of eighteen, suddenly developed teeth which were very soft—that had hitherto been good—so that many cavities appeared in a very short time. They were referred to me by Dr. Bourne to suggest something that could be done. I asked a lot of dentists what could be done and I got no answer. Then, merely by a bit of guess work, I applied to these two youngsters a large amount of ultraviolet light. Dr. Bourne reports that the condition has been greatly ameliorated—that the teeth have hardened again, and are perfectly satisfactory for the ages of these two boys. They were both boys who had good food and lived under good conditions; they usually spent most of their summers in bathing suits at camps or elsewhere. But evidently they could not get a sufficient amount of ultraviolet light to control this condition. They had no rickets and, except for their dental condition, were in perfect health.

These were only two cases, of course, but whether this condition can be met by codliver oil as well as by ultraviolet light, I don't know. To tell two active growing boys to take codliver oil is, from a medical point of view, a joke; they won't take it. But they will amuse themselves by getting thoroughly tanned under an ultraviolet light. That is new and interesting to them, and can be applied successfully because it is a novelty. These are two cases of what seems to me an interesting correlation between the gen-

eral condition of the patient, which is evidently a calcium deficiency, and a serious dental lesion. At the start of the condition these boys faced the threat of having nothing but fillings in their mouths. This is an observation which could be very easily extended by the dental profession. You see these cases and we medical men do not. It would be very interesting to find out whether these two observations are merely two isolated cases, or whether the remedy of a moderate amount of ultraviolet light may prove to be useful in such acute necroses of the teeth.

*George David Stewart, M.D., F.A.C.S.* (*New York City*): If I should say anything at all it would be merely flippant. A wise Frenchman once said that old age was a subject in which youth was never interested. I am not interested in teeth; I am interested only in bridges, and that is the reason I cannot speak very clearly at this time.

If you will allow me to be irrelevant and flippant, I will take you back and tell you a story—take you to a very cold country where even the forest is hidden, where the bays are frozen over—and tell you the story of a boy who had his first toothache. The house was cold, there was no central heating plant. The boy walked the floor most of the night. In the morning he was driven five miles across a frozen bay, and the fellow that drew the tooth that was aching was a blacksmith. He did it with the old-fashioned turnkey, and I suppose Dr. Gillett is the only survivor here besides myself who remembers that instrument of torture. And there (indicating a scar) is where a piece of the jaw came out. I have carried that scar ever since.

Years afterward I was practising in a mining town and had to draw the teeth of the miners. Some of them were magnificent teeth—there were no dentists, remember! A big fellow came in one day who was six feet six inches tall, and said: "I have an aching tooth." I looked at it; it was carious. I didn't know how to fill it, and there was nobody that did know. I got the forceps on (I had a little office of two rooms). The first thing the patient could catch hold on was the door; this came off the hinges. In the outer office there was a big safe (God knows for what—some enterprising salesman had palmed it off on my predecessor); he clutched that in passing, and I got the tooth. It was a tricuspid with diverging cusps, so that I got some of the jaw—and to some extent got even for the loss of my own.

As I sat here listening to you tonight, I was reminded of a little verse of Robert Burns' on the toothache. There are other verses, but I am only going to give you one, and you won't understand that:

"A'doun my beard the slavers trickle,
I throw the wee stools o'er the mickle,
While round the fire the giglets keckle
To see me loup,
And, raving mad, I wish a heckle
Were i' their doup."

That is what I was wishing for when my tooth was taken. Tonight I thought over and over again of all those toothaches of mine and how I wished "a heckle were in the doup" of the fellow who had to pull them. The memories that came back were vivid indeed.

Gentlemen, a minute more and you will see that I don't know anything about teeth. To illustrate my knowledge, let me tell you of two men who, out on the plains, were attacked by a buffalo bull. One man went up a tree and the other into a hole, but as the bull went by he came out. The bull went for him again, and he ducked in. This play went on for a few moments until the fellow in the tree said impatiently: "Why in the name of God don't you stay in that hole?" The other replied: "Now, you are just like a lot of people who talk without knowledge; *there is a big bear in that hole!*"

*Henry S. Dunning, D.D.S., M.D., F.A.C.S.* (*New York City*): I do not know when I have enjoyed a meeting as much as this one. I think this discussion has been a fine thing for dentistry and also for medicine. I would like to make a plea that I have made many times before at dental meetings, and that is, to the younger men of the profession, to work more in the clinics and hospitals, and institutions; and to go amongst the poor, and to learn more about disease at first hand. In order to really know what disease is, we must actually treat a great many patients, and we cannot learn very much by reading books. We cannot all be scientists nor can we all be research workers; but I think that we are nearly all clinicians. If we are such, we should give part of our time to clinics. I believe that one of the failings of dentists, as a rule, is that they get too busy early in their professional life, and do not get in the habit of doing clinical work, as do medical men. It is second nature for the medical man to work in clinics and hospitals. He would be lost without his hospital affiliations. I do not believe there is a medical man in this room tonight who is not connected with some institution where he is thrown in contact daily with disease, and sickness, and misery. Every dental practitioner should have the same training, and should work in hospitals and clinics beside his medical brother, so that he too will be familiar with disease and learn the language, and understand the picture of sick people.

*Dr. Cecil*: There is very little I can add to this very interesting discussion. Dr. McCall, I thought, brought out an excellent point in his discussion of the faculty of judgment in deciding what we shall do with foci of infection. The medical man, of course, in approaching this problem in a particular case, goes to the dentist exactly as he goes to the nose-and-throat man, asking for an opinion and for advice. He doesn't always take the advice he gets, but he wants to have the benefit of that advice, at any rate.

I think very often a dentist is influenced, in the case of his own patient, by a sort of pride of workmanship in disliking to see some beautiful dental work destroyed. This, of course, doesn't come into play for the nose-and-throat man, who has a natural antipathy to tonsils any way, and doesn't mind taking them out! As a matter of fact, in my work with arthritis, I have often had to override the conservative laryngologist who had passed favorably on tonsils the removal of which seemed necessary. After all, as I said in the beginning of my address, that is one of the functions of the medical man. He must take the opinions that he gets from various specialists, weigh them, and try to decide what is best for the patient.

I am sorry that no one discussed Vincent's infections, those spirochetal infections that appear to originate in most cases from infected teeth, and are becoming more and more important to the medical man—Vincent's angina and trench mouth, the infections in the cheek (I refer to abscess), and gangrene of the lung, bronchiectatic cavities, and so forth. This seems to be one of the coming fields for dental hygiene. These infections are sometimes quite serious, and it is one of the problems that the dentist certainly has to handle. We are finding in our medical work, and in some of the experimental work that is now being done, that salvarsan has a very salutary effect on these infections, particularly if taken early.

There is little more to be said. I just want to give my encore to what Dr. Dunning said about working in institutions. I am sure that every man who has spent ten or twenty years of his life in Bellevue Hospital would accept nothing in exchange for the experience he gets there. I believe that institutional training is absolutely essential in the education of every medical man.

*Dr. Miner* (*in conclusion*): I have only a few comments to make in closing. From this meeting tonight, which is greatly stimulating, it is quite evident that there is more active sympathy and more active coöperation between the dental and medical professions in New York than in other parts of the country. This coöperation is bound to benefit both groups, and the patient especially; and the example set here is bound to be followed elsewhere.

I think we ought to discuss fearlessly and frankly our present difficulties, for only in this way can any progress be made towards eliminating them. Dr. Tracy spoke of the ferments in dental education. These are bound to be beneficial, for truth will be evolved by those ferments, which will enable us to build substantially.

Helpful as it is for the physician to refer a patient to the dentist for advice and help, it frequently is just as helpful for the dentist to refer the patient to the physician for advice and opinion. It is sometimes difficult to arouse the keen interest of a physician in a patient who is apparently well, but in these days of health examinations and the development of preventive medicine, this difficulty will soon be a thing of the past.

# MEDICO-DENTAL CASE RECORDS: EIGHTH REPORT[1,2]

## A Clinico-Pathological Study

BISSELL B. PALMER, D.D.S., F.A.C.D., and MALCOLM W. CARR, D.D.S.

*New York City*

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## I. Introduction

A chronic focus of infection, even though it is inconspicuous and apparently trivial, may be the dominant etiologic factor in producing any one of a large group of systemic diseases, most of which develop insidiously and progress slowly (Stevens). The sequelae of a primary focus of infection depend upon the virulence of the infection and the resistance of the patient. Thus, some individuals are capable of resisting what is apparently an overwhelming load of infection, whereas, other individuals readily manifest symptoms of secondary lesions

[1] The previous reports were published in the *Journal of Dental Research:* (1) 1926, vi, p. 283; (2–4) 1927, vii, pp. 115, 275, 457; (5–6) 1928, viii, pp. 73, 579; (7) 1929, ix, p. 89.

[2] Presented at a session of the Eighth General Meeting of the International Association for Dental Research, Royal York Hotel, Toronto, Canada, March 24–26, 1930.

that have resulted from apparently trivial primary infections. In many cases however, instead of producing definite metastatic lesions, focal sepsis results in a general state of chronic invalidism, characterized by general lassitude, mental depression, headache, neuromuscular and articular pains, febrile attacks, malnutrition with subsequent loss of weight and anemia. This type of reaction is described in the following case record.

## II. Case TX-5:*[3] Toxemia*

### GENERAL HISTORY

The patient, a man 33 years of age, was admitted to the hospital[4] on April 19, 1928, for observation and diagnosis. He complained chiefly* of an overwhelming feeling of lassitude and malaise, and an increasing languor and indisposition to exertion.*

*Family history.** His father and mother, and a brother and a sister, were all living and well. The family history was negative for any record of disease that might be related to the patient's illness. He had been married four years; had no children.

*Habits.** The patient smoked cigarettes excessively (thirty a day); did not indulge in alcoholic beverages; was employed as a salesman.

*Past medical history.** Seventeen years ago he was operated upon for a ruptured appendix. Five years ago he had a moderately severe attack of influenza, and has had several recurrent attacks. Two years ago he was operated upon for a right inguinal hernia. For the past few years he has had intermittent swelling and inflammation of both heels, which has caused much discomfort. He gave no history of scarlet fever, diphtheria, typhoid fever, or venereal disease.

*History of present illness.** For about a year the patient had been cognizant of a general feeling of lassitude and malaise, with an increasing indisposition to exertion. He had had frequent attacks of frontal headache, for which glasses had been prescribed, but without giving relief. He had been troubled with "catarrh" for several months. In the mornings he had difficulty in clearing from the pharynx the thick

[3] Words and phrases followed by an asterisk have been explained in the section on "notes and comments" of previous reports. See footnote 1.

[4] The Fifth Avenue Hospital, New York City.

foul-smelling mucus formed during the night. The irritation occasioned by this mucus caused the patient to have paroxysms of coughing in the morning. The nose, however, was clear and without excessive discharge. For the past three weeks he has had a "cold," from which he has been unable to free himself; and has noticed an increase in that languor which now had become distressing, and made it difficult for the patient to carry on his routine work. He slept poorly, had no desire for food, and had lost weight.

PHYSICAL EXAMINATION

Examination showed a well developed man, robust in stature, although generally appearing to have lost some weight and being chronically ill.

*Eyes:* reaction to light and accommodation* was normal.

*Mouth and teeth. Clinical examination.*—There was a heavy deposition of salivary calculus and advanced chronic suppurative gingivitis (periodontoclasia).* There were many infected roots, extensive dental caries, and fistulae from the infected roots and carious teeth. Free pus exuded from the subgingival pockets of infection and from the several fistulae. Oral hygiene had obviously been neglected. *Roentgenographic examination.*—Roentgenograms showed extensive alveolar absorption, advanced periapical infection (chronic rarefying osteitis,* with granulomata and cystic degeneration) of the many remaining roots and carious teeth. The mandibular anterior teeth were the only ones that had not become involved in this generalized destructive process.

It was believed that the oral foci of infection were the dominant etiologic factors in the patient's general condition, and it was recommended that all the remaining infected roots and carious teeth be removed, except the six mandibular anterior teeth.

*Naso-pharynx.* The mucous membrane of the nose appeared normal. There was no deviation of septum, and the breathing space was adequate. The posterior pharynx was highly inflamed, injected, and very irritable.

*Tonsils:* small, and did not appear to be infected.

*Sinuses:* no evidence of infection.

*Chest.* The lungs were clear and resonant* throughout. There

were no râles. Film of the chest shows no infiltration or consolidation in the parenchyma of the lungs. There is increase in the markings throughout the chest from former respiratory infections. There is no evidence of pulmonary tuberculosis* involving the parenchyma of the lungs.

*Heart:* not increased in size.* The sounds were clear and regular. $A_2$ was louder than P.** There was a slight blowing systolic murmur at the apex.*

*Abdomen:* no tenderness,* rigidity,* nor masses.* The liver was not palpable.* (Scar: former operation in the right inguinal region.)

*Extremities:* reflexes were active and equal. There was a lesion on each heel. These lesions were smooth, erythematous, and slightly raised. There were no papules or pustules.

## CLINICAL PATHOLOGY (LABORATORY REPORTS)

During the period of observation the patient's temperature was slightly elevated (98.8–100.5); the pulse rate ranged from 70 to 95. The respiratory rate was normal.

*Weight:* 140 pounds.

*Blood pressure:** systolic, 100 mm.; diastolic, 70 mm.

*Urinalysis.** Amount, normal; specific gravity, 1,015; reaction, alkaline; albumin, faint trace; sugar, acetone, diacetic acid, absent. *Microscopic examination.*—Casts, occasional hyaline; red blood-cells, absent; white blood-cells, few.

*Hematology.** Hemoglobin, 100 per cent; red blood-cells, 5,000,000; white blood-cells, 12,000; polymorphonuclear leukocytes, 74 per cent; lymphocytes, 24 per cent; mononuclear leukocytes, 2 per cent; non-lobulated neutrophilic leukocytes, 28 per cent.

*Blood chemistry** (mg. per 100 cc.). Urea nitrogen 16.3; uric acid, 2.0; sugar, 85.

*Blood complement fixation test:** cholesterol-alcohol, negative.

*Kahn test:** negative.

*Kidney functional test.* (Phenolsulphonphthalein test):* first hour, 55 per cent; second hour, 12 per cent; total, 67 per cent.

## DIAGNOSIS

(A) Toxemia from oral sepsis.* (B) Epidermophytosis (atypical).*

### OPERATION AND TREATMENT

Although this patient had a severe degree of oral sepsis, resulting from the extensive dental caries, the general physical examination showed that there had been little systemic or organic secondary infection (see summary p. 179), the chief manifestations of the primary focus having been the patient's subjective feelings. Under normal circumstances for a patient from whom many teeth are to be removed, operation in several stages is recommended, particularly where there are manifestations of secondary infection. This patient, however, was exceedingly nervous and apprehensive of any surgical procedure, and gave a history of severe reaction immediately following the injection of procain-suprarenin for the removal of a tooth several months ago. The patient's psychological estate, and probably high resistance to any general anesthetic, and the history of severe reaction following the previous injection of procain, had to be taken into consideration in determining how the many infected teeth and roots might be removed with the minimum psychological and surgical shock. It was decided to perform the operation in one stage under ether anesthesia, unless some contradicting circumstance developed during the procedure. Accordingly, on April 24, with the patient under nitrous-oxide-ether anesthesia, twenty-three teeth (or their remaining root-fragments), were removed. Irregular edges of the alveolar process were resected. The anatomical communication with the left maxillary sinus was immediately closed by a flap operation and horse-hair sutures. The operating time was one hour and ten minutes. The patient's condition when he left the table was good. The pulse rate was 100; the respirations were 25.

### PROGRESS NOTES

The patient's reaction following the operation was satisfactory. On the first day there was a slight elevation of temperature (100.5), and the pulse rate was 95. The temperature and pulse rate returned to normal on the second day. The patient showed no signs of any systemic exacerbation (excepting as noted below); there were no untoward subjective symptoms. Daily, non-lobulated, neutrophilic leukocyte-counts were made. On the day after the operation the non-

lobulated neutrophilic leukocytes had increased from 28 per cent to 55 per cent. The second day after the operation the count reached a "high" 65 per cent, and a total increase of 37 per cent. This was a very interesting defensive reaction. On the fifth day the percentage was again within normal limits. There was also an increase in the percentage of the polymorphonuclear cells, although not to so great a degree. The patient was given the usual post-operative care, and had an uneventful recovery from the operation.

*Medical treatment.* The only medical treatment was routine drugs for pain and elimination, and special treatment of the heels (dressed b.i.d. with formalin 1 per cent). On April 28th the patient was discharged from the hospital, "improved."

## FOLLOW-UP EXAMINATION

The patient was seen for follow-up examination in January and July, 1929. The following data are a summary of the examinations made on July 10, one year and three months after the patient's discharge from the hospital.

*Subjective symptomatology:** lassitude, malaise, and sleepiness had entirely disappeared. The patient felt much improved, did not fatigue easily, and has resumed his usual daily routine. He slept better at night, and his appetite was improved. His head pains had discontinued, and he no longer felt the need for the eye-glasses that had been prescribed for the frontal headache. He had been free from the frequent attacks of "colds," and the annoying profuse exudation of foul mucous in the pharynx had been entirely eliminated. The throat and sinuses were giving no trouble.

*Objective examination.** The patient appeared brighter and had a better color, having lost the sallow complexion of one who is suffering from chronic disease or toxemia. Temperature, pulse, and respiration were normal.

*Weight:* 182 pounds.

*Blood pressure:* systolic, 120 mm.; diastolic, 80 mm.

*Mouth and teeth:* normal healing; antrum opening, closed; mucous membrane, normal. The mandibular anterior teeth had been scaled, and the periodontal tissues treated. The patient wore a full upper and a partial lower denture, both of which were satisfactory and comfortable.

*Pharynx:* slightly red but not irritable. (The patient still smoked cigarettes excessively.)

*Tonsils:* Small, smooth, and regular; not inflamed; no exudate, and probably not infected.

*Lungs:* respiratory sounds, clear and resonant throughout.

*Heart:* not enlarged to percussion; no murmurs, no thrills.

*Abdomen:* no masses, tenderness, or spasm. Liver and spleen not palpable.

*Extremities.* The epidermophytosis had entirely cleared up, and both lesions healed.

*Clinical pathology. Urinalysis.*—Amount, normal; specific gravity, q.n.s; reaction, acid; albumin, sugar, acetone, diacetic acid, absent. *Microscopic examination.*—Casts and red blood-cells, absent; white blood-cells, few.

*Hematology.*—Hemoglobin, 100 per cent; red blood-cells 5,000,000. (January red blood-cell count showed 4,300,000); white blood-cells 9,500; polymorphonuclear leukocytes, 76 per cent; lymphocytes, 22 per cent; eosinophilic leukocytes, 2 per cent.

## III. General Summary

The patient was admitted to the hospital for observation and diagnosis, complaining chiefly of lassitude, malaise, and general indisposition for work. He had lost weight, slept poorly, lost appetite for food, and had been subject to frequent colds. He had continually an excessive exudation of foul mucous in the pharynx, and suffered from chronic frontal head pain.

Examination showed a slight elevation of the evening temperature, weight below normal, and hypotension. There was leukocytosis, but no anemia. Urinalysis showed albuminuria and hyaline casts. Blood chemistry was normal, except for the blood sugar which was low. Kidney functional tests were normal. Roentgenogram of the chest eliminated pulmonary tuberculosis. Wassermann and Kahn tests were negative. Joints were normal. Heart was normal in size, although it elicited a systolic murmur. There was no arthritis. There were many foci of infection in the mouth, twenty-three teeth or their remaining root-fragments showing either advanced periodontal or periapical disease.

The absence of general disease, as eliminated by the various exami-

nations and laboratory tests, and the marked evidence of advanced oral sepsis established a diagnosis of general toxemia, with oral sepsis as the dominant etiologic factor.

The infected teeth were removed in one operation with general anesthesia, without serious exacerbation or untoward sequlae.

Follow-up examination one year and three months after the patient's discharge showed a complete and permanent relief from the subjective symptoms mentioned above. There was now no elevation of temperature, and no leukocytosis. The patient's weight had increased 40 pounds. The blood pressure had returned to normal. Albuminuria and hyaline casts had disappeared. The systolic murmur was no longer elicited. The patient felt that his general health had returned to normal, and he was now carrying on a full schedule of his routine daily activities without fatigue.

## IV. Conclusions

(1) Oral sepsis may be the dominant etiologic factor in the development of general toxemia.

(2) Such toxemia, when not having long continued and in the presence of a relatively high resistance, may exist without serious organic degenerative changes.

(3) The elimination of the primary focus of infection will probably abate, and possibly completely relieve, the secondary symptoms.

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# THE CHEMISTRY AND STAINING REACTIONS OF KERATIN

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## I. INTRODUCTION

The presence of protein in dental enamel has been shown by Bödecker and Gies (1, 2). That this protein is keratin has been demonstrated by Rosebury and Gies (3). In view of these facts, the properties of this type of protein become matters of general interest to the dentist.

## II. CHEMISTRY OF KERATIN

Keratin, a tough, horny substance, is the chief constituent of the epidermal layer of the skin; also of hair, feather, nail, hoof, wool, tortoise shell, etc. As a constituent of the sheath of medullary nerves, it is known as neurokeratin. It is found also, as ovokeratin, in the membranes of egg shells of many animals. As the chief substance in the outer layer of the skin, it has a protective function. Often it becomes impregnated with calcium salts, which render it harder and more protective, as in nail, horn and hoof.

In the conventional classification of proteins, keratin is placed with the albuminoids—simple proteins that are characterized by insolubility in neutral solvents. Although the members of the keratin group show dissimilar qualities, and differ somewhat in composition,

as a class they have certain properties in common. Differences in composition among some keratins are indicated in *Table 1*. In addition to the elements shown in *Table 1*, arsenic has been found in some keratins. According to Buchtala (5), keratin in elephant epidermis contains considerable quantities of iron. The high percentage of sulphur, owing to the large content of cystine, is a striking feature in the composition of this class of proteins. The cystine content of a number of keratins is given in *Table 2*, where it may be seen that there

TABLE 1

*Percentage composition of some keratins (4)*

| SOURCE | CARBON | HYDROGEN | NITROGEN | SULPHUR | OXYGEN* |
|---|---|---|---|---|---|
| Wool | 50.65 | 7.03 | 17.71 | 4.61 | 20.00 |
| Epithelium | 51.53 | 7.03 | 16.64 | 2.18 | 22.32 |
| Nail | 51.00 | 6.94 | 17.51 | 2.80 | 21.75 |
| Neurokeratin (brain) | 56.99 | 7.53 | 13.15 | 1.87 | 20.46 |
| Hair (man) | 50.65 | 6.36 | 17.14 | 5.00 | 20.85 |
| Egg membrane | 53.92 | 7.33 | 15.08 | 1.44 | 22.23 |

* Calculated by difference

TABLE 2

*Percentage of cystine in some keratins (6)*

| SOURCE | CYSTINE |
|---|---|
| Hair (human) | 14.0 |
| Nail (human) | 5.2 |
| Egg membrane (hen) | 7.6 |
| Horn (ox) | 6.8 |
| Hoof (horse) | 3.2 |

are wide variations in the quantity of cystine in keratin from different sources. The proportions of amino acids other than cystine vary within wide limits. Glutamic acid, for example, which is present in sheep-horn keratin to the extent of 17.2 per cent, occurs in keratin from goose feather to the extent of only 2.3 per cent.

Keratin gives most of the typical color reactions for proteins; *e.g.*, biuret, Millon, and xanthoproteic reactions. There is some question as to whether it responds to the reactions for tryptophane (Adamkiewicz and Hopkins-Cole tests). According to Barrit (7), the Adam-

kiewicz test is positive; Bogue (8) claims the test is negative. Rosenthal (9), working in this Laboratory under Dr. Gies' guidance, found that the Hopkins-Cole test is negative.

Although easily altered by alkalies, the sulphur being readily removed, the resistance of keratins to changes by other agents is striking. It has been suggested that this resistance is due to a special linkage in the molecule. The keratins are insoluble in water and alcohol, and remain practically unaffected by boiling water at ordinary pressures. If heated in water in a sealed tube, at 150°C. or higher, keratin decomposes with the elimination of hydrogen sulphide or mercaptan. As a group the keratins are insoluble in cold dilute acid, but as the strength of the acid is increased, swelling takes place and disintegration is effected by boiling. However, the resistance of some keratins to acid is very great. According to Unna and Golodetz (10), the keratin in the envelope of the horn and hair cells is not dissolved by fuming nitric acid.

Alkaline solutions markedly affect keratin, causing swelling and a loss of sulphur, and complete decomposition upon boiling. Treatment of keratin with hot alkaline solution as weak as 1 per cent $Na_2CO_3$ causes a change. This instability to alkalies is responsible for the depilatory effect of alkaline solutions. Wilson and Daub (11), using lime water, showed that the first action on hide is a slow disintegration of the cells of the Malpighian layer of the epidermis (containing the so-called "young" keratin), leaving the hair resting loosely in the empty follicle. As a result of the action of lime water, keratin is changed to keratose, which is readily soluble in neutral and alkaline solutions, precipitable by acid, and easily digested by trypsin. The corneous layer of the skin containing the more resistant keratin, somewhat separated from the true skin after the treatment, can easily be removed along with the hair.

The addition of sulphides greatly increases the unhairing action of lime liquors on hides. Merrill (12) believes that this is due to a reaction between keratin and mercapto (SH) ions, which so alter the structure of the protein that the residues are more readily attacked by the hydroxyl ions.

Keratin is resistant to the action of pepsin and trypsin, although so-called "young" keratin is digested by trypsin. When keratin

from horn is treated with a strong solution of ammonia, or with glacial acetic acid, a "keratin" solution consisting of decomposed keratin is produced. This is used for coating capsules which should be insoluble in the mouth and stomach, but absorbable from the small intestine. Röhm (13) showed that alkaline tryptic preparations can be used as depilatory agents, the action being exerted on the "young" keratin of the malpighian layer of the skin.

Gies and Strauss (14) described a method for the preparation of keratin from horn which is applicable to keratinous tissues in general. The method is essentially as follows: Horn is scraped with a knife to produce thin shavings. These are transferred to water at 40°C. for several hours, to soften the particles; then are subjected to the action of pepsin in 0.2 per cent HCl, following by that of trypsin in 0.25 per cent $Na_2CO_3$. The residue is then thoroughly washed successively with water, hot alcohol, and ether. Prepared in this manner, the material does not include "young" keratin, which occurs only in newly formed cells. The proteins of newly formed epithelial cells are not keratins, but later are converted into keratin.

In general keratins are very resistant to the action of bacteria. Since the epithelial tissues consist of layers of keratinized cells that cover all the free surfaces of the animal body, the physiological importance of the resistance of undamaged skin to the action of bacteria, for the mechanical protection of the underlying tissues and the prevention of direct infection, is obvious.

### III. STAINING REACTIONS OF KERATIN

So far as the author is aware, there is no report of a stain that is specific for keratin. In a study of goat skin in this Laboratory under Dr. Gies' guidance (15), the author, using Mallory's aniline-blue connective-tissue stain (16), found that in untreated skin this stain gave an orange color to the epidermal layer and to the hair-root sheath of the skin, while the underlying collagen took on a deep-blue color. Preparations of keratin from several sources gave the same response. After skin had been treated with milk of lime, to remove the epithelial structures, only the blue stain was obtained. The specificity of this stain for the epidermal layer of the skin accords with the relationship between it and keratin. This result was obtained by treating the skin successively as follows:

| | |
|---|---|
| 1. Formalin—10 per cent | 24 hours |
| 2. Alcohol—80 per cent | 24 hours |
| 3. Alcohol—95 per cent | 24 hours |
| 4. Absolute alcohol | 24 hours |
| 5. Mixture of equal parts of absolute alcohol and ether | 24 hours |
| 6. Thin celloidin solution (7 grams of celloidin dissolved in 100 cc. of a solution of equal parts of absolute alcohol and ether) | 4 days |
| 7. Thick celloidin solution (15 grams of celloidin dissolved in 100 cc. of the above solution—6) | 4 to 7 days |
| 8. Small blocks cut and mounted | |
| 9. Blocks hardened in 80 per cent alcohol | 8 hours |
| 10. Sections, 10 microns thick, cut and transformed to 80 per cent alcohol | |

Sections were subjected to this treatment:

| | |
|---|---|
| 1. Clove oil until sections became transparent | |
| 2. Alcohol—95 per cent | 30 minutes |
| 3. Water | 10 minutes |
| 4. Aqueous solution of acid fuchsin—0.5 per cent | 5 minutes |
| 5. Stain consisting of 0.5 gm. of aniline blue, soluble in water, and 2 gms. of Orange G (Grübler) dissolved in 100 cc. of 1 per cent aqueous solution of phosphomolybdic acid | 20 minutes |
| 6. Water | 45 minutes |
| 7. Alcohol—95 per cent | 10 minutes |
| 8. Blot with filter paper and add xylol; repeat blotting, followed by xylol three times | |
| 9. Xylol balsam | |

Turley (17), continuing the work in this Laboratory under Dr. Gies' guidance, found that the specific epidermal structures that acquire the orange color are the corneous layer of the skin and the inner hair-root sheath.

Chase (18) found, in harmony with the foregoing observations, that Mallory's connective-tissue stain imparted analogous colors to comparable strata of decalcified developing enamel (human fetus at term) and plantar epidermis, which he stated was "evidence in support of the contention of Gies that the organic constituent of enamel is a

protein of the nature of keratin." In a recent paper on the development of dentine, Orban (19) reproduced a picture from a paper by von Ebner showing a section of a tooth in a pig embryo stained by Mallory's method. The enamel epithelium is yellow in this picture, plainly indicating the presence of keratin in the original tissue.

## IV. SUMMARY

1. A brief description of the chemistry of keratin is given.

2. It is shown that Mallory's connective-tissue stain is specific for the epidermal layer of the skin, indicating an important relationship between this stain and epidermal keratin.

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[1] See also the succeeding paper in the present issue. *Journal of Dental Research*, 1930, x, p. 187. [*Ed.*]

# A BIOCHEMICAL STUDY OF THE PROTEIN IN DENTAL ENAMEL[1]

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## I. INTRODUCTION

For about fifty years the question whether enamel subserves a dynamic function as a living tissue, or acts only as a passive masticat-

[1] A preliminary report, on "a simplified procedure for the separation and identification of protein in dental enamel," was included in the proceedings of the Seventh General Meeting of the International Association for Dental Research: Rosebury and Gies, *Journal of Dental Research*, 1929, ix, p. 299.

[2] William J. Gies Fellow in Biological Chemistry at Columbia University. Second appointee, July 1, 1928–January 31, 1930. See Miller: *Journal of Dental Research*, 1929, ix, p. 742.

ing and protective surface, has been a matter of controversy between two schools of dental histologists. One school has been partial to the hypothesis of enamel vitality dependent upon a contained protoplasmic groundwork; the other, assuming the total mineralization of enamel, has considered it devoid of vital functions. Curiously, each side has asserted repeatedly that its hypothesis has been established and the other invalidated; yet both schools retain their convinced representatives.

Before 1888 the vitalistic view was upheld by Abbot (1, 2), C. F. W. Bödecker (13, 14), Heitzmann (29, 30, 31), and Thompson (49). These workers agreed that the apparent sensitiveness of enamel to the instruments of the dentist indicated its vitality. This deduction, although not now appearing so axiomatic as it did then, was nevertheless logical enough as a working hypothesis. But it is an interesting commentary on the obstacles to scientific progress that, as the record clearly indicates, the working hypothesis before long assumed the proportions of an article of faith, to which adherence became a matter of duty rather than of rational conviction. Thus, experimental findings (apparently exclusively histological) were interpreted with great enthusiasm in the preferred direction; imagination augmented evidence to the semblance of proof; and the grain of truth actually disclosed was all but lost in the subsequent vigorous disapprobation of the opposing school. C. F. W. Bödecker, in 1878 (13), had described what he believed to be protoplasmic fibers and delicate interlacing fibrils lying between the rods in ground sections of enamel stained with gold chloride. In 1880 Abbott confirmed Bödecker's observations (1), and in 1887 (2) mentioned fragments of fully demineralized enamel obtained by treatment with 1 percent chromic acid. His description of these fragments tallies remarkably well with that in the body of the present paper. Thompson, as early as 1887 (49), expressed the noteworthy opinion that, in the enamel, "the salts of lime are deposited. . . in an organic matrix of horny matter, *keratine*." All of these workers were firmly convinced, because of this evidence, of the presence of *living* matter, and consequently of the occurrence of vital phenomena, in enamel. Thompson (49) put the case most succinctly: "It has been conclusively demonstrated that there are areas of living-matter in the enamel, and that this living-matter is in

direct connection by an anastomosis more or less regular and continuous with the contents of the dentinal tubuli. If this be true, then indeed there is osmosis by which nutrition is conveyed to the enamel, however minute and inappreciable it may be."

During the same period, others remained unconvinced that the enamel is a vital tissue. Sudduth (48) and Allen (3) are notable in this connection, although their view on the subject is not clearly expressed in the record. Sudduth spoke of the enamel as a "coat of mail," a remark of which Heitzmann (31) warmly disapproved. It is interesting to find that J. L. Williams, later the strongest opponent of the vitalistic group, subscribed at this time to the view of C. F. W. Bödecker in regard to the "fibers of living matter" (53). In 1898 C. S. Tomes (50) published the results of a histochemical study of enamel prepared by grinding away the dentin. On demineralizing it with dilute nitric acid, there remained only a few shreds of residue, which on microscopic examination were found to consist of dentin, cementum, and Nasmyth's membrane. He also tested for the presence of soluble protein in enamel, with negative results. By incineration of enamel he found evidence of minute traces of organic matter. He concluded that "there is very little organic matter in enamel, not enough for quantitative estimation." He believed the bulk of the material usually considered organic to be merely water. (See page 207.) In 1896 J. L. Williams (54) reached the same conclusion, on histological grounds, by means of a series of photomicrographs. He was unable to find any confirmation in his studies of the previous work of the vitalist group; indeed, in a somewhat heated footnote, he speaks of the "vain imaginings" of the Heitzmann school. Nevertheless, nearly thirty years later Williams (55) again changed his mind, and became convinced of the existence of an organic matrix in enamel, although he concluded that it could have only a mechanical function.

The cause of the vitalistic school was given renewed impetus in 1905–6 by the publication of C. F. Bödecker's (5, 6) celloidin-decalcification method, whereby the organic groundwork of enamel could be retained in its natural relation during the process of demineralization, by substituting a supporting mass of celloidin for the dissolved mineral salts. With the aid of this method, Bödecker described the organic matrix

as consisting of enamel-prism sheaths, tufts, and lamellae. In a later paper (7), these structures are well illustrated with photomicrographs of the matrix. These findings were confirmed early by Fleishmann (23), Fischer and Mayrhofer (21), Rygge (46), and others; more recently by Malleson (39), Mummery (43), and Orban (44). Malleson, employing a method somewhat different from Bödecker's, concluded that "the residual material is a prism cortex or cuticle" resistant to acids. Orban found the enamel lamellae of Bödecker, but considered the tufts to be lamellae projected onto one plane. He believes there are two kinds of lamellae: one developing from the outer epithelium of the enamel organ, and becoming hornified; the other developing from the inner epithelium, incapable of hornification, and consisting of "various kinds of tissue." The evidence is apparently entirely histological. Bödecker felt justified in assuming (7) that the matrix he demonstrated is not only organic, but also protoplasmic, in the sense that it provides the medium for metabolic changes in enamel. He has amplified this view in later papers (9, 10, 11). Rygge (46), on the other hand, while conceding the presence of the matrix, considered it so completely mineralized in normal enamel as to preclude the possibility even of fluid interchange. Similarly, Williams (54), erstwhile supporter of the view of total mineralization, became convinced in 1923 of the existence of an organic matrix, but could see no justification for the assumption that metabolic activity occurs in enamel.

The balance of evidence seemed to favor the existence of an organic groundwork in enamel, but some doubt still remained, even after Bödecker's presentation of his "three proofs" (8). Hopewell-Smith (32, 33, 34), in particular, remained altogether unconvinced, offering many arguments in support of his contention that the enamel "may be regarded as wholly inorganic" (33). In 1923, Gies (25), at a meeting of the New York Section of the International Association for Dental Research, where Bödecker demonstrated the presence of an organic matrix in enamel (10), "suggested that until it is shown *directly* that the matrix contains or is free from protein matter, a reasonable scientific doubt regarding the relationship of the matrix will persist," and "said it would give him pleasure to endeavor to determine whether protein is present." His findings, obtained with Bödecker's collaboration, proved conclusively the presence of protein in dental

enamel (26). In the paper describing the results, Gies said in part: "The foregoing proof that the matrix contains albuminous matter did not include a determination of the nature of the contained protein. It might be keratin, the chief protein constituent of all other ectodermal structures in the higher animals, but this is merely a reasonable guess. An attempt will be made to ascertain the quality and relationships of the protein. Pending such a determination, any discussion of the organic matrix as a factor in the nutrition of the enamel must remain speculative" (26).

The present investigation is a sequel to the series of papers by Bödecker and by Gies (10, 11, 12, 26) in the *Journal of Dental Research* (vi, 1926). The work was undertaken as an attempt to establish, by chemical means, the ultimate truth behind this old controversy. The successful development of the method, to be described, of obtaining the acid-insoluble residue of enamel from human teeth in a form relatively convenient for chemical handling, then led directly to a study of the character of the material as a basis for a consideration of its relationships and function.

## II. SEPARATION OF THE PROTEIN

### *A. Insoluble protein*

1. *Selection and preparation of human teeth.* In the several methods of preparing enamel in this work, as well as in the procedures for its demineralization, care was taken from the outset to avoid as far as possible all influences that might conceivably alter a contained protein. The use of hardening and preserving agents such as alcohol or formalin, of dentin-staining agents such as safranin, or of heat, was therefore precluded. Accordingly, human teeth from which the enamel was to be obtained were in all cases freshly extracted. In the interval between their extraction and their utilization, usually several hours, they were kept in water or normal saline solution. Before the enamel was prepared, the teeth were cleaned as follows. Bone, adherent soft tissues, and gross tartar were removed by scraping with a knife under cold water. The teeth were then thoroughly scrubbed with a stiff brush and soap, washed under cold water, and immersed for about 30 seconds in 5 percent hydrochloric acid. In this way the surface of

the enamel was demineralized sufficiently to insure the detachment of any albuminous or other surface contaminant, such as mucinous films or shreds of Nasmyth's membrane. The findings of Chase (19) indicate the importance of this step. After this superficial demineralization, the teeth were again scrubbed. For the preparation of enamel by any of the methods to be described, teeth reasonably free from defect were selected; carious areas and abraded parts, and all suspicious surface discolorations that could not be removed with a stone under cold water, were avoided. Teeth from which the enamel was to be prepared by chiselling were used immediately; those intended for the other method of preparation were permitted to dry in air at room temperature.

*2. Preparation of enamel.* The preparation of pure enamel was very difficult. At first, by way of preliminary experiment, enamel was prepared in a manner that obviously promised a large yield; i.e., teeth were sectioned transversely at the neck with a separating disc, and the dentin removed from the crown with burs. It was soon found, however, that, in enamel samples made this way, no matter how painstaking the preparation, dentin invariably appeared in the demineralized residues. Hence this method was abandoned early. Another method was that of desiccation and fracture. Teeth were permitted to dry in air in a warm place for several days. In the dry teeth, the dentin had contracted away from the enamel to some extent, so that, when the teeth were crushed carefully between the beaks of pliers, flakes of enamel often separated neatly from the dentin. By exercising care in the selection of these fragments, and thoroughly cleaning their dentinal surfaces with stones in an engine, it was possible to reduce greatly the danger of dentin contamination. Many of the preparations made in this way were entirely free from dentin. But the positive assurance that the product was uniformly pure was lacking, even at best; and it was considered essential to look further for a more perfect method. Nevertheless, this method of desiccation, because of its simplicity and generous yield, was employed in a number of instances for preparations in which the presence of dentin was immaterial.

It was apparent that enamel cannot be prepared with dependable purity by any method in which the entire thickness of the enamel cap

is obtained in the product. It was necessary, therefore, to devise a method in which only a part of the thickness of the enamel cap would be removed, leaving the dentin unexposed. Attempts to prepare enamel by grinding the dry surface with burs, although this requirement was fulfilled, proved very laborious and wasteful, the yield being exceedingly small. Grinding with carborundum stones or discs under water, the enamel being collected by sedimentation and decantation, was also unsatisfactory because the product was grossly contaminated with carborundum.

The method finally adopted, and used for all "pure" preparations on which crucial experiments were conducted, was that of chiselling, as follows. A series of longitudinal grooves was cut on the axial surfaces of each crown, under running cold water, with a separating disc in an engine. The grooves were cut to a depth of about 0.5 mm. at the thickest part of the enamel. By selecting for this purpose teeth with full contours, all possibility of involving the dentine was precluded; and, by terminating the grooves well within the cervical limit of the enamel, freedom of the product from cementum was also assured. The grooved teeth were again scrubbed and washed, and dried with filter paper. Enamel was chipped from the edges of the grooves with a sharp straight chisel, collected on clean white paper, carefully freed from visible dust particles with a camel-hair brush, and transferred to clean glass vials, in which it was kept until needed. Teeth as nearly perfect as could be obtained were used for enamel prepared in this way; *fresh*, to prevent the flaking of enamel that occurs under stress in desiccated teeth; and free from areas of enamel undermined by caries, since such parts fracture easily under a chisel. To prevent contamination of the product *with scurf from the head or hands*, a cap and rubber gloves were worn during the chiselling. At least four teeth, and often eight or more, were used for the preparation of a single specimen of pure enamel.

*3. Demineralization procedure.* The acid of choice for demineralization was selected according to the principle mentioned at the beginning of this section, and on the basis of preliminary experiment. It seemed probable that past failures to find protein in enamel by ordinary histological methods depended upon the acid used. Chemical instability of the protein might have effected its hydrolysis and

disappearance under the influence of nitric or other strong mineral acids; or, because of physical delicacy or fragility, its masses might have been disrupted and scattered by the violence of the chemical reaction. While in the light of subsequent findings the first precaution was superfluous, the latter turned out to be well founded (see page 205). Accordingly, acetic acid was selected because of its slight dissociation, and because of the probability that at low concentrations, sufficient for demineralization, it would not destroy the identity of the enamel protein. By preliminary experiment on tribasic calcium phosphate, and on crudely prepared enamel, successively, a concentration of 1.5 percent of acetic acid, renewed occasionally, was found to be effective under the conditions to be described. Lower concentrations of this acid, although slowly effective, permitted growth of fungi in the demineralized residues. The 1.5 percent acetic acid appeared to be strong enough to prevent this difficulty, for there were no signs of fungi in any residue prepared with it. Boric acid was added to the acetic acid in a few instances to prevent such growths, but later was omitted as superfluous.

The following demineralization method was used. Tall glass cylinders, of about 400 cc. capacity, were each fitted with a rubber stopper perforated to hold vertically a short length of half-inch glass tubing, which projected about an inch into the cylinder. For each product a collodion bag, made on the inner surface of an 18 mm. test tube [method of Gies, given by Hawk and Bergeim (28), p. 73] and cut short, was attached to the lower end of the glass tube. The pulverulent enamel was placed within the collodion bag and washed to the bottom with 1.5 percent acetic acid. The bag was then suspended in the cylinder, which was filled with the acid to the same level as that in the bag. The upper end of the glass tube was closed with a rubber stopper, and the assembly covered with an inverted beaker as a dust cap.

This device has many advantages. Soluble and insoluble proteins, and also diffusible and indiffusible proteins, are automatically separated under control. The enamel is held in a small transparent container, where its condition can be seen at a glance. It need not be disturbed during the process of demineralization except for the occasional removal of the entire stopper-bag unit to replenish the exterior acid. Yet the small quantity of enamel present may be acted upon by the

total volume of acid in the assembly, because of the free diffusion of the acid through the collodion membrane. The rate of demineralization is affected by the height of the column of liquid; the dissolved mineral salts, diffusing outward through the collodion bag, fall by gravity to the bottom of the column, thereby inducing a circulation that assures the continual movement of fresh acid to the enamel. Finally, when the process is complete, the demineralized residue of enamel remains at the bottom of the collodion bag, where portions may be readily obtained as needed with a pipette inserted through the glass tube above.

The progress of demineralization was followed by testing the fluid in the cylinder at intervals for phosphate. In the crucial tests, in which pure enamel was used, three negative phosphate tests of the bottom portions of the exterior liquid, obtained on consecutive days without changing it, were accepted as an accurate index of the completion of demineralization. The time required for the completion of the process varied with different specimens from three or four days to two months, depending entirely, so far as could be determined, on the amount of enamel present. No significant time variations between different samples of enamel were observed.

The identification of the insoluble protein is described in Section III.

### *B. Tests for soluble protein*

The dialytic method of demineralization, described above, is as effective for the separation of soluble proteins from mineral matter as for the retention of the residue. Few proteins diffuse through collodion; the bulk of any soluble protein in enamel would remain within the collodion bag. This was attested by the fact that the fluid in the collodion bag of an assembly containing *dentin*, after filtration, responded positively to the biuret reaction. But several similar tests of the interior and exterior fluids, in assemblies containing pure enamel, were completely negative to the biuret test.

In order to determine conclusively the presence or absence of soluble protein in enamel, a preparation of pure enamel was put up with 1.5 percent acetic acid in the usual way, especially for this purpose. Both the exterior and the interior fluids were decanted regularly and preserved for testing. The interior acid contained, presumably, any

soluble, non-diffusible protein; the exterior acid, any soluble diffusible protein. At 48-hour intervals during the six days required for the demineralization of this specimen, the exterior and interior acid fluids were decanted into bottles and replaced with fresh acetic acid. After demineralization, the collected total of the *interior* acid was filtered, neutralized to litmus (external indicator) with 2 percent sodium hydroxide, and evaporated at 40–45°C. over warm water to a volume of about 15 cc.—approximately one-tenth of its original volume Neutrality of the solution, and the low temperature of evaporation, minimized the danger of hydrolysis of any contained protein. This fluid was divided equally between two small porcelain crucibles of uniform size and color. Into a third crucible of the same kind was placed a similar volume of water as an additional control. An equal volume of 10 percent sodium hydroxide was then added to each crucible, and a few drops of Gies' biuret reagent (28) added to the control and to one of the test crucibles. This careful manner of controlling the reaction is essential, because a positive biuret reaction, when dealing with minute quantities of protein, may be overlooked without this precaution. In this case, however, no trace of coloration change occurred; the test was entirely negative, confirming the previous results.

The collected total of the *exterior* fluid was also filtered, evaporated, and tested in a similar manner. This also failed to respond to the biuret reaction, controlled as in the preceding instance.

### III. IDENTIFICATION OF PROTEIN IN THE ENAMEL RESIDUE

Tests for soluble protein in enamel having been conclusively negative, only the insoluble residues remained to be studied. It is noteworthy that, in approximately fifty assemblies in which enamel was demineralized, including about twenty that contained enamel prepared by the method of chiselling, typical residues were obtained in appreciable amounts in all cases. The initial tests of these residues were conducted to repeat and extend the experiments in which the protein character of such products was demonstrated by Gies (26).

#### *A. Physical examination*

A notable characteristic of the demineralized residue of enamel, as it appears in the collodion bag, is its drab, yellowish color. This was

observed as the first preparation approached complete demineralization, and was seen thereafter in all of them, whether the enamel was pure or contained dentin. Preparations of dentin alone, however, put up for comparative studies on the residues, were found to have the pale cream-color characteristic of that tissue. On removing with a pipette some of the particles of enamel residue, to transfer them to a microscope slide, some protein qualities became apparent. The particles were light and fluffy, as evidenced by their tendency to settle very slowly from suspension. Many adhered tenaciously to the walls of the pipette. Rubbed between the fingers they were soft, with no gritty evidence of crystalline structure. When dried on a microscope slide in the air, they were not easily dislodged even under a stream of running water.

The following description of particles of enamel residue, as seen under a microscope, is based on a large number of observations, including coverslip preparations in acetic acid, dry films, water and balsam mounts, and preparations stained by various agents. The demineralized enamel-residue occurred as delicate fragments, having a collapsed, crumpled appearance when wet, and showing fissures, caused by contraction, when dry. The particles were colorless, pale yellow, or light brown, depending partly on their thickness. Thin particles were difficult to make out except under reduced illumination, and disappeared from view entirely as the iris diaphragm was opened. The particles often appeared completely amorphous, or showed an uneven granularity and marking, apparently owing to irregular folding and distortion. Occasional particles, in the absence of distortion, presented the longitudinal and transverse striations typical of enamel sectioned longitudinally to the rods; and, rarely, a particle exhibited the honeycomb structure of enamel sectioned transversely to the rods. In these preparations, dissimilar extraneous particles, invariably present in the various products, undoubtedly represented dust from the air. See the footnote on page 208.

Particles of enamel residue thus examined may easily be differentiated from dentin demineralized in the same way. The matrix of dentin retains its characteristic structure, apearing very much the same after demineralization as before; it never presents the crumpled, torn appearance so characteristic of the more delicate enamel residue.

This microscopic difference was the final check on the purity of the enamel prepared by the method of chiselling. These facts having been noted after preliminary study, all demineralized pure specimens of enamel prepared thereafter were examined critically under the microscope for dentin. Each was found to be entirely free from it.

### *B. Protein color tests*

Throughout this work the amounts of pure enamel used in the tests were small, because of the great difficulty in preparing it. The amounts of residue remaining after demineralization were correspondingly much smaller. The collodion-bag assemblies were excellent for dealing with these small amounts, since they prevented dispersion and loss of the residues. Yet at best the quantity of residue available for individual tests was so minute—consisting of only a few tiny particles —that it was necessary to adapt most of the ordinary biochemical qualitative tests to use with the microscope. Three common color tests for protein were thus adapted, with results that agreed in all cases.

The *biuret test* was performed on the residue micro-chemically, as follows. Gies' biuret reagent, prepared to contain as much copper as possible without precipitation of the hydroxide, was employed. Particles of pure enamel residue were pipetted from a collodion bag, allowed to fall to the tip of the pipette, and transferred with an accompanying drop of acetic acid to a clean culture-cell, which was then filled with the reagent, and quickly adjusted under a low power. A lavender color promptly developed in the thinner fringes of the particles, and slowly extended until it pervaded them. At first the color was delicate, but after a few minutes it deepened sufficiently to be visible to the naked eye. This color test, which is the most general for proteins, and which is not given by any insoluble substance except protein, was repeated several times on four different preparations of chiselled enamel, and never failed to respond positively, thus confirming Gies' finding (26).

*Millon's test*, which is not so reliable as the biuret test, was performed as follows. Particles of pure enamel residue were pipetted from a collodion bag to a clean slide, and the drop permitted to dry in air. A drop of Millon's reagent was then added and the slide

warmed gently. The particles developed strongly the typical red color. Millon's test was also conducted in small test tubes in the ordinary way. It was also convenient and economical to perform the test occasionally on particles adhering to the walls of a pipette, by drawing Millon's reagent into the pipette and warming, the red response of the particles being observed macroscopically. All of these tests were sharply positive.

The *xanthoproteic test*, to which, like the Millon test, many non-protein substances also respond, was conducted on particles of residue on a microscope slide. It was positive in all cases.

## IV. CLASSIFICATION OF THE INSOLUBLE PROTEIN

The insoluble protein of body-surface structures and of the nervous system, in the higher animals, is keratin. Therefore the enamel, being ectodermal in orgin, might be supposed to contain this albuminoid. Keratins, although differing more or less widely, have the following characteristics in common: they (a) are relatively resistant to chemical disintegration; (b) are not digested by pepsin or trypsin; and (c) contain relatively high percentages of cystine, and hence of labile sulphur. A study of the enamel protein was, accordingly, projected along these lines.[3]

### *A. Action of acid and alkaline solutions*

The xanthoproteic test, performed microscopically, showed incidentally that enamel protein is markedly resistant to disintegration by concentrated nitric acid, which produces in it no visible change other than the xanthoproteic yellow. This observation was confirmed by subjecting enamel protein to the action of concentrated nitric and hydrochloric acids by the method used for alkaline solutions, as indicated below. No disintegration was observed.

The action of concentrated sodium hydroxide solution on the enamel protein was tested microscopically in the following manner. Particles of enamel residue were pipetted to a cover slip and dried in air. A culture cell, with a depression 2 mm. deep and having a capacity of

[3] The preceding paper in this issue, by Dr. Karshan, presents a general review of the chemical properties of keratins: *Journal of Dental Research*, 1930, x, p. 181.—[*Ed.*]

about 0.8 cc., was filled with the reagent, rimmed with vaseline, and the cover slip inverted over it. This was fixed under a low power; a typical residue particle was brought into focus; and, with the aid of an eyepiece-micrometer ruled in squares, an outline drawing of the particle was made. Changes in outline could be observed over a period of hours by comparing the particle with the drawing. Tested in this manner, the enamel protein showed little or no change in outline in either 10 percent or 20 percent sodium hydroxide in five hours.

To test the effectiveness of this method, comparative studies were made in the same way on a number of known substances. Tendon collagen (dry, ox tendo achilles) and hide collagen (prepared hide-powder) disintegrated in 10 percent sodium hydroxide in two hours or less; dentin residue, in the same reagent, disintegrated in from three to five hours; nail filings swelled at first, and disintegrated within four hours. Twenty percent sodium hydroxide acted more slowly in each case.

Additional information relating to the action of strong alkali was obtained incidentally in observations on the behavior of various materials in boiling 20 percent sodium hydroxide solution prior to testing for sulphur (page 202): Dentin residue disintegrated most readily, albino hair and nail filings (both keratin) somewhat more slowly; all yielding a clear solution. Scurf (keratin) disappeared still more slowly, and neurokeratin[4] and enamel protein disappeared only after prolonged boiling, and then incompletely, each yielding a yellowish, turbid solution. The first of the three keratin characteristics mentioned was, therefore, demonstrated: the enamel protein is highly resistant to chemical disintegration.

### *B. Action of digestive enzymes*

The residue was subjected to peptic digestion. Since the proteins in dentin are completely digested by pepsin (page 201), their presence

[4] The neurokeratin employed in this and succeeding experiments was prepared from cat cerebrum which had been kept in 95 percent alcohol; subjected to pepsin digestion for 48 hours at 37°C. and then to trypsin digestion for 48 hours at 37°C.; extracted with boiling 95 percent alcohol for 24 hours and then with boiling ether for 24 hours; dried in air; washed with three changes of water, and kept in water. The residue gave the micro-biuret and micro-Millon tests.

in this experiment would be immaterial. Accordingly, a relatively large amount of enamel, containing some dentin, was prepared by the method of desiccation. After demineralization in the usual way, most of the supernatant acid was pipetted from the collodion bag, and the residue transferred to a 100 cc. conical glass by perforating the bag and washing the residue into the glass with pepsin solution—0.2 percent pepsin in 0.2 percent hydrochloric acid, freshly prepared in each instance. Pepsin solution was then added to make 50 cc. In a similar system pure dentin residue was used; a third contained only the pepsin solution as a control. The levels of the sediment of enamel and dentin residues were noted, and the three systems incubated at 37°C. All were thoroughly stirred at intervals of about an hour during twelve hours, and then permitted to remain in an incubator for an additional twelve hours. At the end of that time the system containing dentin residue presented only a few particles of sediment, which on microscopic examination were seen to be extraneous matter. In the system containing enamel protein, on the other hand, little or no reduction in the amount of residue could be observed. This, on microscopic examination, showed typical enamel-protein particles, and a few particles of extraneous matter similar to those in the other preparation. The control remained free from sediment.

This experiment was repeated, but the systems were incubated without stirring. After 24 hours, the system containing dentin residue showed only a slight reduction in the amount of sediment; that containing enamel residue, none. Microscopic examination revealed the typical enamel residue in the one, and dentin, somewhat frayed and vacuolated but recognizable, in both. After the addition of fresh pepsin solution, and incubation for an additional 24 hours, *with frequent stirring*, the dentin disappeared from both systems. Further incubation of the enamel-residue system for a total of seven days at 37°C. failed to produce any apparent reduction in the bulk of residue, or any recognizable change in the microscopic appearance of the particles.

The enamel residue from the 7-day peptic digestion was then subjected, in the same conical glass, to the action of trypsin. The acid mixture was neutralized to litmus with 2 percent sodium hydroxide, decanted, and the residue washed with water. After sedimentation,

the water was poured off and replaced by a freshly prepared solution of trypsin (0.3 percent) in 0.5 percent sodium carbonate. This was incubated at 37°C., with a control system containing fibrin in an equal quantity of the trypsin solution, and an additional control containing a portion of the trypsin solution alone. All were stirred at frequent intervals. After 24 hours the fibrin had disappeared, but the enamel residue remained apparently unreduced in bulk, and typical microscopically. No sediment appeared in the trypsin control. Characteristic reactions of this pepsin-trypsin residue are indicated on page 205.

### *C. Reaction to tests for labile sulphur*

The resistance of the enamel protein to acid, alkali, pepsin, and trypsin classified it with the keratins. This was confirmed by the lead test for labile sulphur. By preliminary experimentation on nail filings and other known keratins, the following procedure was found to insure the utmost delicacy in the lead test, which at best is not a delicate reaction. The protein was disintegrated as completely as possible in a small amount of boiling 20 percent sodium hydroxide. The mixture was cooled, and equally divided between two small test tubes. One drop of a dilute solution (1–2 percent) of lead acetate was then added to one tube, and one drop of water to the other, and the color of the two tubes compared against a white background. This was repeated with additional drops of lead acetate solution and water. By this method albino hair, scurf, and nail filings, in small quantities, responded with a moderate brown color, settling as a brown flocculation on standing. Neurokeratin showed only a very slight darkening of the test solution. Dentin residue was completely negative, even when a large quantity was used.

Since dentin showed no evidence of contained labile sulphur, a demineralized residue from enamel obtained by the method of desiccation was used for this test because it provided an ample quantity. The disintegrated alkaline mixture responded to the lead acetate by darkening slightly—a positive result, less marked than those obtained with nail filings, scurf, and hair, but somewhat stronger than that obtained with neurokeratin.

## V. COMPARATIVE STAINING REACTIONS

### *A. Mallory's stain*

Studies with Mallory's triple connective-tissue stain were undertaken in the hope that, by comparing the enamel protein with other keratins and with collagens, additional light might be thrown on the chemical relationships of the enamel protein. Bayliss (4) has suggested that the mechanism of staining reactions, in particular those of the anilin derivatives, is a physical rather than a chemical process, and depends upon adsorption that either results from a decrease in surface tension, or occurs by virtue of the electric charge at the surface of the particles. However, Karshan (36)[5] found that keratins, in sections of skin treated with Mallory's stain, characteristically show the coloration of the orange-G dye, whereas the collagens are stained by the anilin blue. This work was repeated in part, and extended to include the enamel keratin.

Mallory's stain was prepared, with Grübler dyes, according to Mallory's directions (40). After experimenting extensively with various methods and staining-time relations, the following procedure was adopted for the comparative tests because it gave the most consistently uniform results. A microscope slide having been coated with a very thin layer of albumin fixative, particles to be tested were dried on it in a drop of water or 1.5 percent acetic acid. When dry, the slide was run successively through xylol, alcohol—absolute, 95, and 50 percent—and water, and placed for twenty minutes into Mallory II solution—anilin blue (5.0 gm.) and orange-G (2.0 gm.) in 100 cc. of phosphomolybdic acid (1 percent aqueous). Acid fuchsin was not used—its red color was found to confuse the result, and clearer differentiation was obtained without it. After being stained, the slide was washed in running water for 10 minutes. This was sufficient to insure removal of all dye not firmly fixed in the particles, and was essential for clarity in the result. The preparation was then run up "through the alcohols" into xylol, and mounted in balsam.

In each case particles or teased fibers were used. Body-surface keratins (nail filings, scurf, skin scrapings, and albino hair) stained

[5] See also the preceding paper in the present issue: *Journal of Dental Research*, 1930, x, p. 181.—[*Ed.*]

consistently and evenly yellow. Collagens (ox tendo achilles, prepared hide-powder, and dentin residue) stained blue, with occasional patches of yellow. Enamel keratin and neurokeratin persistently stained unevenly—most particles, blue; some, blue and yellow; others, yellow; a few were unstained. These two keratins showed a striking similarity in this relation; it was difficult, in fact, to distinguish between them. Passage through peptic and tryptic digestions resulted in no marked difference in the reaction of enamel protein with Mallory's stain. No other procedure with Mallory's stain, of the many tried, yielded results that were so consistent, or so markedly differential for keratins and collagens, as did the method given. Yet in all of the tests there was a tendency of the materials employed to stain in the manner indicated.

It was found that (a) the use of albumin fixative was indispensable to a uniform result; it not only assisted the adhesion of particles, but helped to produce even staining. (b) The reaction of the drop of liquid used to float the particles on the slide seemed to be immaterial. Water, 1.5 percent acetic acid, 0.2 percent hydrochloric acid, and 1 percent sodium hydroxide all failed to alter the staining reactions of scurf, the material selected for testing this point. (c) Fixation in Zenker's fluid, required according to Mallory's directions, produced no change in the staining reactions of scurf, all other conditions remaining the same. (d) Immersion for 24 hours in peptic digestion mixture interfered somewhat with the staining of scurf, introducing blue patches. Enamel residue, after peptic digestion, also showed an increased preponderance of blue. Since dry pepsin was colored blue in Mallory's stain, this result may have been caused by adsorption of pepsin by the particles. (e) The analytical staining of dentin, enamel residue, and neurokeratin, using separate solutions of anilin blue and orange-G, prepared according to Mallory's formula but with one dye omitted in each case, showed that all three materials are stained by each dye, but more markedly by the blue.

### *B. Pianese's stain*

Another staining procedure was a modification of a method of Pianese—stain IIIb, given by Mallory and Wright (40, p. 80). The following procedure was found the best of several tried. The slide

is prepared and run through xylol, and the "descending alcohols," in the manner described for Mallory's stain. It is then stained in saturated, aqueous, picric acid for five minutes, rinsed in water, and stained for five minutes in the Pianese IIIb solution—malachite green (0.5 gm.), acid fuchsin (0.1 gm.) martius yellow (0.01 gm.), distilled water (150 cc.), and 95 percent alcohol (50 cc.). The slide is then washed for five minutes in running water and run up "through the alcohols" and xylol, and into balsam. By this method, all of the keratins studied—nail filings, albino hair, skin scrapings, neurokeratin, and enamel keratin, including the pepsin-trypsin residue—stained green; collagens—tendon, hide-powder, and dentine residue—stained lavender to rose color. Large particles often showed irregular staining in the center; but, in general, the results, in spite of the great variation in thickness of the particles, were remarkably uniform.

This result led, by adaptation, to a simple method of demonstrating the presence of the protein matrix in enamel. A mixture of equal parts of the Pianese stain and 5 percent hydrochloric acid was used to demineralize a few fragments of enamel in a cover-slip preparation under the microscope. By this direct means the enamel protein was observed to remain as a green fringe around the mass of uncolored enamel, as the latter was progressively demineralized by the acid. The delicacy of the matrix was indicated by the circumstance that bubbles, escaping from the surface of the enamel fragment, frequently detached and carried off portions of the matrix. In fact, if a stronger acid is used than that given (2.5 percent hydrochloric), the bubbling is so vigorous that no part of the enamel matrix remains intact. This corroborates the hypothesis mentioned on page 194, indicating an advantage of demineralization with a weak acid.

The same method of demineralization and simultaneous staining, when applied to dentin, colors the matrix of that tissue rose-colored or lavender, as in the first instance. Since the Pianese method as described provides a means of staining the dentin and enamel matrices contrastingly, it is recommended as a histochemical procedure.

### VI. REACTION OF THE ENAMEL PROTEIN WITH SODIUM SULPHIDE

Mixtures containing soluble sulphides have long been used as depilatories. Mullin (42), in a review of the albuminoids, mentions the

swelling action of sulphide solutions on horn, hair, and nail, and refers to a subsequent peptization. This was tested, under the microscope, on nail filings, hair, and skin scrapings, with saturated aqueous sodium sulphide solution. Each of these materials was found to swell at the instant of contact with the solution. During the interval of observation no evidence of disintegration was seen, nor was any other change apparent. That this swelling effect was due to the action and concentration of the sulphide-ion was shown by the finding that water, 2 percent sodium hydroxide, and a strongly alkaline solution of iron sulphide (in the sodium sulphide as an impurity, prepared and tested independently) were without visible effect on these keratin masses.

Enamel keratin and neurokeratin, on the other hand, showed no swelling in the sodium sulphide solution during many observations. In explanation of this difference between the body-surface keratins which swell, and the more internal keratins which do not, the hypothesis is offered that the swelling action is one of aqueous imbibition by the particles, initiated by the sulphide ion. Consequently, only those keratin masses, i.e., the body-surface keratins, will swell which are dehydrated in their natural state. The circumstance that this group of keratins is richer than enamel keratin and neurokeratin in cystine sulphur may also have a bearing on this difference, the cystine group in keratin being the point of attack in alkaline solution.

The initial experiments with sodium sulphide were done by mounting dry enamel-keratin particles under a cover slip, and allowing a drop of sodium sulphide solution to flow into contact with them while observing the effect through a microscope. When the solution met a particle there was an instantaneous development of green color in the particle. This was repeated many times. The green coloration varied in intensity with different preparations, but was never absent. The enamel residue from peptic and tryptic digestions also showed it. Neurokeratin, nail filings, and dentin from a preparation containing no enamel, showed no such pigmentation. Among the possible reasons for the coloration, the most likely is the presence of iron in the particles. The details of a further study of this possibility will be published in a succeeding paper.

## VII. DETERMINATION OF THE AMOUNT OF PROTEIN IN ENAMEL

### *A. Review of literature*

A number of attempts have been made to determine the amount of organic matter in enamel. In 1808 Berzelius,[6] from results of incineration, calculated 2 percent of "membranes and water;" in 1844 Von Bibra,[6] in the same way, found 3.59 to 5.97 percent of organic matter. In 1895 Tomes (50), believing that the loss he obtained by incineration—5.8 to 7.5 percent—was due to water, concluded that "there is very little organic matter in enamel; not enough for quantitative estimation." In 1913, Evans (20), with data for proportions of carbon dioxide and nitrogen in two samples of enamel, calculated the amount of organic matter as between 1 and 2 percent. Unfortunately, the enamel he used was prepared by removal of dentin with burs, a method which, as has been shown, does not completely eliminate it. In 1927, Karlström (35) confirmed, by incineration, the findings of Von Bibra and Tomes. In eight tests, the loss of weight varied from 3.0 to 7.0 percent, averaging 4.6 percent. Karlström also determined the nitrogen in enamel by the micro-Kjeldahl method, and found 0.016 to 0.100 percent, averaging 0.047 percent, indicating a percentage of protein of 0.1 to 0.66 percent, averaging 0.3 percent. In 1928 Sprawson and Bury (47) prepared enamel with files in a manner similar to the chiselling method used in this work, and found it contained 0.020 to 0.023 percent of nitrogen, indicating a protein percentage of 0.14 to 0.15. On the basis of carbon determinations, they calculated 0.18 to 0.21 percent of protein.

### *B. Methods and results*

*1. Incineration.* Two different samples of enamel, prepared by the method of chiselling, were dried to constant weight at 105°C. and weighed in covered crucibles that had been previously heated to constant weight. Each of these portions of enamel was then incinerated over a low Bunsen flame. Definite charring occurred in each case, and a slight film of soot was deposited on the cover during the initial phase of the burning. In order to secure complete ashing, a few drops of pure concentrated nitric acid were added to the cooled gray mixture,

[6] Cited by Karlström (35).

which upon re-heating quickly became uniformly white. (A determination of the ash from the nitric acid showed the quantity for 1.0 cc. to be unweighable.) Each ash was reduced to constant weight by heating repeatedly for 10-minute periods, and cooling in a desiccator for at least 30 minutes before each weighing. The ensuing losses by incineration are subject, *for the calculation of protein content*, to reduction for (a) the quantity of free water in enamel *in vivo*, all of which was probably expelled at 105°C.; and also for (b) the possible loss by volatilization of constituents of the enamel other than protein. (The results obtained by the direct micro-method, given below, indicate that non-protein losses by incineration were large.) The chief analytical data of these tests, which accord with those of Von Bibra, Tomes, and Karlström, are summarized below:

| | Preparations of enamel | |
|---|---|---|
| | 1 | 2 |
| | Milligrams | Milligrams |
| Weight of enamel taken | 176.9 | 259.9 |
| Weight of ash obtained | 168.6 | 249.4 |
| Loss by incineration | 8.3 | 10.5 |
| | Percent | Percent |
| Proportion of the enamel lost by incineration (protein plus other volatile materials) | 4.69 | 4.04 |

*2. Direct micro-method.* Enamel, prepared by the method of chiselling (*A* below), was dried to constant weight at 105°C., divided into two portions, and each portion treated as follows. The dry enamel was weighed in a micro-Gooch (filter) crucible, and demineralized in the crucible with 5 percent hydrochloric acid. The residue was dried to constant weight at 110–115°C., and weighed on a micro-balance. The residue was then washed with 5 percent hydrochloric acid, dried and weighed, and the washing and drying repeated to constant weight. Two washings were required in one case, three in the other. Finally, the residue was ignited and the ash weighed. No ash was obtained in one case; in the second, the ash consisted of black and brown particles—almost certainly dust impurity from the air.[7]

[7] Enamel, as prepared for this work, is unavoidably contaminated to some extent, in spite of the greatest care, by dust from the air. The presence of extraneous impurities in the residues in the collodion bag-systems has already been noted. In these micro-analytic determinations, a single insoluble dust particle in the mass, by passing into one of the half-samples, might, because of the great delicacy of the method, account for the difference obtained in the results.

Another sample prepared by the method of chiselling (*B*, below) was treated in the same manner, but the residue was not incinerated. A third sample (*C*, below) was prepared by the method of desiccation, then freed from dentin by grinding very carefully with stones and thoroughly washing before drying and subjecting it to the micro-method. Since this preparation was more easily freed from extraneous matter than the others, the result obtained with it—the lowest percentage recorded—is possibly closest to the actual value.

The results for content of enamel keratin are given below:

| | Preparation A | | Preparation B | Preparation C |
|---|---|---|---|---|
| | 1 | 2 | | |
| | Milligrams | Milligrams | Milligrams | Milligrams |
| Weight of enamel taken. | 130.400 | 199.995 | 165.783 | 597.800 |
| Acid-insoluble residue at constant weight (keratin plus ash)..... | 0.710 | 0.980 | 0.768 | 1.790 |
| Loss by incineration (keratin)..... | 0.710 | 0.780 | ... | ... |
| | Percent | Percent | Percent | Percent |
| Proportion of keratin in the enamel..... | 0.54 | 0.39 | 0.46 | 0.30 |

These direct results for enamel *keratin* are of the same order of magnitude as those obtained for *protein* in general, by the micro-Kjeldahl method, by Karlström (35) and by Sprawson and Bury (47). This concordance is a further indication that keratin is the only protein in enamel.

I am greatly indebted to Dr. O. Wintersteiner for the micro-analytical determinations.

## VIII. DISCUSSION

The results of this investigation show that the organic substructure of enamel is keratin. The evidence indicates that the enamel protein is more closely allied to neurokeratin than to the keratins of the body surface. Their similar resistance to disintegration by boiling alkali, weak labile-sulphur reaction, failure to swell in sodium sulphide solution, and atypical reaction with Mallory's stain, differentiate them as a

group from the epidermal keratins.[8] In general, neurokeratin and enamel keratin are similar in being internal and not dehydrated as are the external keratins.

The function of keratin in enamel has not been directly indicated by these results. Keratin, although a product of living cells, is itself a lifeless substance and cannot participate in nutritional changes. These facts, the absence in enamel of cellular nuclei and soluble proteins, which are present in all active protoplasm, and Gies' recent finding (27) that enzymes are absent from enamel, indicate conclusively that fully formed enamel is not the seat of any living process. There is, on the other hand, no incompatibility here with the permeability of the enamel to water and simple substances that was shown in 1917 by Gies (24),[9] and confirmed by Bunting and Rickert (15), Livingston (38), and Klein and Amberson (37). Permeability to stains under certain conditions has been shown by Von Beust (51, 52), Caush (16, 17), Marshall (41), Williams (55), Bödecker (9), Fish (22), and Chase (19). The failures of Pickerill (45), Rygge (46), Bunting and Rickert (15), and Hopewell-Smith (33), to obtain similar results, and the conditions of pressure employed by Marshall (41), Bödecker (9), and Fish (22), may mean that the diffusion of larger molecules through enamel does not occur in life, but can be brought about by artificial conditions. It is evident that the finding reported in the present paper, that enamel contains no soluble protein, accords with this principle, since it shows that enamel is not permeated by protein molecules from lymph or saliva. In any case, as has recently been shown by Klein and Amberson (37), diffusion through enamel must proceed very slowly; and it is difficult to believe that such diffusion can account for any important physiological process.

The function of the keratin, if indeed it is not merely a residuum of

[8] Chase, in a recent report (*Journal of Dental Research*, 1929, ix, p. 288) stated that the middle stratum of developing human enamel is colored by Mallory's stain in the manner characteristic of keratinized epidermal tissues. In an earlier paper, however, Chase reported (*Anatomical Record*, 1927, xxxvi, p. 239) that the interprismatic substance of [fully formed?] enamel becomes blue with Mallory's stain, the color most frequently taken by the enamel keratin in the present study. Possibly the keratin, during the development of enamel, is so changed that its reaction with this stain is altered.

[9] See also the succeeding paper in the present issue: *Journal of Dental Research*, 1930, x, p. 215.—[*Ed.*]

the living structure of the enamel organ, may be nothing more than a mechanical contribution of toughness and elasticity, which a horny substance would impart to a brittle mineralized mass. This possibility has been suggested by Williams (54) and Gies (26), but overlooked by Hopewell-Smith (33). Possibly the permeability of enamel has no other influence than, by maintaining the tissue in a moist state, to reduce the liability to fracture.

## IX. SUMMARY AND CONCLUSIONS

The objects of this research have been the isolation of the protein of dental enamel, and a study of its physical and chemical characteristics. There was devised a method that included (a) the preparation of enamel, freed from other dental tissues, and (b) its demineralization with dilute acetic acid, in collodion bags, by which all of the protein was obtained unchanged and kept easily accessible.

From the results of the tests for soluble protein in the fluids of the demineralizing assemblies, and of the physical and chemical studies of acid-insoluble residues, the following general conclusions may be drawn:

(1) Enamel does not contain soluble protein, and therefore is not traversed by proteins in lymph or saliva.

(2) The acid-insoluble residue consists chiefly if not wholly of protein.

(3) The protein in the residue shows the chemical characteristics of keratin. It appears to be more closely allied to neurokeratin than to the keratins of the body surface.

(4) The proportions of keratin in enamel, after drying to constant weight at 105°C., as found by direct micro-analysis, varied between 0.30 and 0.54 percent (average, 0.42 percent).

Further studies of the enamel protein are under way.

In conclusion, I wish to acknowledge my profound gratitude to Professor William J. Gies for his invaluable guidance in the details of this research, and for the opportunity, during my incumbency of the Fellowship in his name, for intellectual association with as fine a teacher as I have ever had.

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## XI. ADDENDUM

Since this paper was presented for publication, Cape and Kitchin, in a study of "tooth-tissues as observed under polarized light," were "unable to find any trace of keratin in the organic matrix of enamel."[10] They concluded that, "if the matrix of the enamel is keratin, it is evident that we must consider it as a different type of keratin from any other we have examined." "As a criterion for determining the presence of keratin" in enamel, Cape and Kitchin used the birefringence of "scraping of human nail," which had been placed "in 5 percent nitric acid for a period of time sufficient to decalcify a thin section of human tooth, both dentin and enamel." The data in the section of the present paper beginning on page 199 show that, in some respects, the keratin in dental enamel is unlike that in nail. It is possible that Cape and Kitchin, in their treatment of enamel with nitric acid, accentuated the difference between nail keratin and enamel keratin. In the present study, the use of nitric acid was avoided to prevent modification of the enamel protein.

[10] Cape, A. T., and Kitchin, P. C., *Journal of the American Dental Association*, 1930, xvii, p. 193.

# STUDIES OF DENTAL CARIES, WITH SPECIAL REFERENCE TO INTERNAL SECRETIONS IN THEIR RELATION TO THE DEVELOPMENT AND CONDITION OF DENTAL ENAMEL[1]

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*A*. Do substances in the blood pass from dental pulp into dental enamel of living animals? *Hattie L. Heft.*

*B*. Is dental enamel permeable to substances in saliva? *Elizabeth C. Franke.*

*C*. Effects of parathyroidectomy and castration on dentition in albino rats. *Edgar G. Miller, Jr.*

*D*. Dental effects of feeding glandular tissues to albino rats. *Edgar G. Miller, Jr.*

*E*. A new glycoprotein: dentomucoid. *Leila Noland.*

Decay of teeth, except that arising from trauma, may be due primarily to local deficiency in the structure and quality of enamel, or it may result from local specific disintegrative attack on enamel, regardless of normality of the enamel, or it may be caused by both

[1] Reprinted from the *Proceedings of the Society for Experimental Biology and Medicine*, 1917, xv, pp. 5–8.

The findings in the researches mentioned in this reprint, which relate to the "cause, control, and prevention of dental caries," have apparently been generally overlooked despite their age and significance. Some of the completed researches were published in the *Journal of the American Dental Association* and *Transactions of the Dental Society of the State of New York*. Unfortunately, progress in the extensive program of coördinated researches outlined in this report thirteen years ago was halted by events of the World War. Return to this program after the War was prevented by a shortage of workers interested in the problems, and also by lack of funds for its promotion. The organization and publication of the *Journal of Dental Research*, and the conduct of the Carnegie Foundation's study of dental education, by presenting more urgent duties, caused further postponement of the work and of its natural extension.—[*W. J. G.*]

these types of influences. In this series of studies we are endeavoring to ascertain whether "influences from the inside," such as those of a nutritional type and involving internal secretions, may be responsible factors in the incidence of dental caries.

Impairment of normal nutritive and endocrinic influences, *by subtraction*, has been induced by extirpation of various glands in albino rats. There were no effects on dentition after thymectomy, thyroparathyroidectomy, or castration; deficient calcification of the teeth (incisors) followed parathyroidectomy.

Modification of normal nutritive and endocrinic influences, *by addition*, has been induced by feeding various glands to white rats. Dental calcification appeared to be (*a*) regularly *decreased* by oral administration of lymphatic, salivary, or thyroid, gland; (*b*) regularly *increased* by oral administration of testicle; and (*c*) wholly *unaffected* by oral administration of corpus luteum, parathyroid, pineal, pituitary, spleen, suprarenal, or thymus.

There were no effects on the general condition or dimensions of the teeth in any of the foregoing experiments.

*Physiological variation* in the composition of the teeth, in albino rats, is relatively slight and not great enough to account for any of the findings that were indecisive.

The well-known *chemical methods* we have employed were found to be adequate to detect significant chemical differences in dentition. Various results of uncertain import have not been due, at any time, to deficiencies in the analytic procedures as such.

Underlying all our experiments on the effects of internal secretions is the assumption that *chemical* changes may take place, *in developing enamel*, through the influence of substances that *originate* outside of, and enter or superficially affect, the cells involved in the production of enamel. If this assumption is unwarranted, it is obvious that internal secretions can have no *direct* chemical effect on the production or condition of enamel. If this assumption is incorrect, internal secretions can have, at most, only *indirect* effects on the development of enamel.

That our assumption in this general regard is correct, however, is

shown by the fact that *trypan blue*, after its intraperitoneal injection into *young* rats, rabbits, and dogs, passes freely into the enamel of *developing* teeth, where the blue pigment seems to remain indefinitely; it does not pass from pulp through dentin into enamel of fully *erupted* teeth. (These particular facts were demonstrated at the meeting of the Society.)

That our assumption in this general regard is justified is shown, also, by the fact that *strontium*, after its oral administration (as the chloride), daily for some time to *young* dogs, accumulates in the solid parts (and is present in the pulp) of the first and second sets of teeth, apparently taking the place of calcium. We have not yet determined whether strontium substitutes calcium, in such experiments, in the enamel of fully *erupted* teeth.

Experiments with *arsenic*, in the forms of salvarsan and arsenite (analogous to those with strontium), in an effort to determine whether arsenic can displace, or associate with, phosphorus in dental calcification, have given us wholly negative results.

Practically all the biochemical results referred to, thus far in this statement, were obtained on teeth *in process of development*. It has been cumulatively evident, as our experiments increased in number and scope, that internal secretions can have little or no effect, directly or indirectly, *on the enamel of fully developed and erupted teeth* (and therefore can have little or no continuing direct bearing on the problem of caries in such teeth) unless one or more *physiological* substances can pass from pulp through dentin into normal enamel, or from oral fluids into such enamel.[2]

We find that water passes freely back and forth through all parts, including the enamel, of fully developed natural extracted teeth. Simple mineral salts such as sodium chloride, and common organic substances such as cane sugar, show similar ability to diffuse back and forth through fully developed natural extracted teeth.

Our results in this general relation indicate that, whether or not there is true nutritive or maintenance *metabolism* in normal enamel, there may be physiological or pathological exchange of materials in

[2] This statement ignores provisionally the possibility that caries may occur from changes in dentin that merely *undermine* enamel.

enamel by *diffusion* from blood through dentin and enamel to oral fluids, and *vice versa*.[3]

In the course of our study of the nature of tooth composition, from the point of view of effects of internal secretions on dentition (in their relation to the problems of cause, control, and prevention, of dental caries), we have found that teeth contain a *glyco-protein* that is closely similar to osseomucoid, and is evidently analogous to, though not the same as, salivary mucin.

A complete study of the properties of this protein substance, which we have named *dento-mucoid*, is now in progress. We have already learned that it remains in teeth during the process of their acid decalcification. It is extractable, from decalcified teeth, with dilute alkalin solutions. It is precipitated, from such alkalin extracts, by mineral acids such as hydrochloric. It is an acid protein that forms colloidal salts. It yields reducing substance similar to glucosamin after acidic hydrolysis.

All of these studies are in progress, together with inqui[illegible] the effects, on dentition in successive generations of albino rats, of treatment with thyroid, of unbalanced diets, and of toxic malnutrition.[4]

[3] Proteins were not among the substances that diffused through the enamel.—[*W. J. G.*]

[4] See the second paragraph in footnote 1.—[*W. J. G.*]

# PRIMARY MOUTH MANIFESTATIONS OF SKIN DISEASES[1]

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## I. INTRODUCTION

The past decade has witnessed a decided change in dental education[illegible]. The trend of this change has been to advance dentistry from a "mechanic" to a "biologic" science, and to place it on a par with medicine as a recognized component of the healing arts. As a result of this movement, more attention is being given to the mouth in its relation to the body. It is now recognized that not only may the mouth (teeth and gums) be responsible for bodily ailments, but also that bodily ailments may be manifested early in the mouth. During the past year I have seen several dermatology cases of special interest to the dentist. These are worthy of citation because of their value in diagnosis, and in emphasizing the interdependence between medicine and dentistry.

Skin and mucous membrane are analogous structures, being derived from the same ectodermic layer of the embryo. Hence, in many skin diseases we expect to find their manifestations in the mucous membrane of the mouth as well as on mucous membranes elsewhere in the body. Spencer, years ago, called attention to this relationship when

[1] Read at a meeting of the New York Section of the International Association for Dental Research, School of Dental and Oral Surgery, Columbia University, March 13, 1930.

he wrote that "it is a familiar biological truth that the organs of sense and teeth (enamel) arise from the dermal layer of the embryo, and that abnormalities may affect all of them." He illustrated his remarks by showing that abnormalities in the eyes of blue-eyed cats are usually accompanied by abnormalities in the ears—these cats are usually deaf; again, hairless dogs (abnormalities of the skin) usually have imperfect teeth (abnormalities of the enamel). That similar abnormalities may be caused by a constitutional disease is self evident and is best exemplified by syphilis, which, in its earlier stages, is a skin disease. When it occurs in the congenital form the effects may be disturbances involving several different organs, each derived from the same embryonal tissue; for example, the enamel of the teeth (Hutchinson), the eye (interstitial keratitis), and the ear (sudden deafness)—the Hutchinson triad of syphilis. The occurrence of a skin rash and mucous patches of the mouth, in the secondary stages of syphilis, is too well known to require comment.

It must be remembered, however, that skin lesions that occur in the mouth are influenced by the oral environment, and may differ on that account. Thus "color" contrast is less striking, owing to the greater transparency of the mucous membrane; and because of moisture and resulting maceration, the early lesions undergo modification or lose their characteristics by secondary infection from oral bacteria. Vesicles and bullae become erosions, and papules are covered with a grayish membrane and may have a central erosion or ulceration." (1).

In addition to syphilis and the exanthematous diseases of childhood, which are commonly known to the dentist, herpes simplex, herpes zoster, lichen planus, and pemphigus occur not infrequently in the mouth. Often the lesions caused by these diseases occur primarily in the mucous membrane of the mouth, to be followed by skin manifestations, which in some cases however do not appear. The cases here cited, representing this group, are of special interest because the lesions that occurred were primary in the mouth and were not followed by skin manifestations.

## II. LICHEN PLANUS

*Case 1.* Male, age 41, an uncle of a dentist, had been under a prominent dentist's care during the past three months, and had been

treated for Vincent's infection. As his condition did not improve, he sought further advice. Examination of his mouth showed a superficial irregular erosion on the right cheek at the molar-bicuspid area. The mucous membrane was purplish red. The dorsal surface of the tongue was covered entirely with small polygonal, mother-of-pearl, gray, raised patches set close together (*fig. 1*). No symptom of pain was noted except slight burning in the cheek area. From the clinical signs a diagnosis of lichen planus was made. Thorough examination of the entire body showed no skin lesions. This diagnosis was concurred in by a prominent dermatologist.

*Case 2.* A middle-aged, western, male school teacher, taking a summer course at Columbia University, was under treatment for thrush of the mouth. This diagnosis had been made by a physician at a prominent western medical center, where the patient had stopped for observation and diagnosis. As his condition did not respond to the usual treatments, he sought further advice at the Clinic of the School of Dental and Oral Surgery of Columbia University. Examination of the mouth showed that, on the sides of both cheeks, in the bicuspid-molar regions, there was a series of superficial configurations which in appearance closely resembled a series of small fern leaves etched in the mucous membrane of the cheek. The outlines of these configurations were grayish-white and the mucous membrane of the cheek purplish. These configurations extended onto the gums, especially of the lower jaw. Clinically, these lesions were not suggestive of thrush, which, usually appearing like fine milk curds set into the mucous membrane, can be scraped off leaving a raw red surface. But these "lines" could not be scraped off the cheek. In addition, the mouth was moist in contradistinction to the dryness in thrush. Scrapings of these areas were negative for *Oidii albancans* when examined under the microscope. Clinically, the lesion resembled the "Farnkrautblatt" (German for male fern leaf) variation of lichen planus of the cheek (*figs. 2 and 3*). Careful examination did not reveal any skin lesions. This diagnosis was concurred in by the Department of Dermatology of the School of Medicine.

*Case 3.* A middle-aged woman was seen in consultation with her physician. The patient developed hoarseness over a year ago. As it did not improve under treatment, she was studied by various promi-

FIG. 1. Lichen planus of tongue

FIG. 2 FIG. 3

FIGS. 2 AND 3. "Farnkrautblatt" variation of lichen planus of cheeks

FIG. 4. Lichen planus of tongue

FIG. 5. Lichen planus of cheek

FIG. 6. Lichen planus of tongue

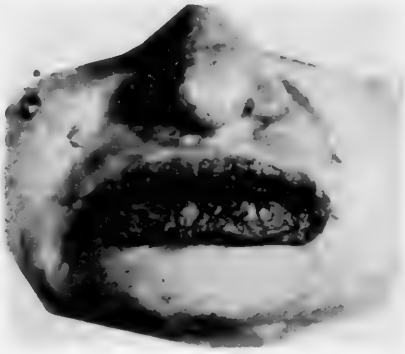

FIG. 7. Pemphigus of face and lip

nent physicians who excluded such conditions as papillary growth of the vocal cords and epithelioma, tuberculosis of the larynx, and syphilis. At that time a small oval lesion was noticed on the left of the dorsal surface of the tongue, but no significance was attached to it. Recently, a similar lesion formed on the right side of the tongue, prompting the physician to seek further advice. Examination showed a small oval-shaped lesion, approximately 12 x 6 mm., at the middle third of the dorsal surface of the tongue on the left side. The lesion was superficial, resembling an ellipse drawn with grayish-white chalk and having a lace-work mosaic in the center (*fig. 4*). The lesion on the right side was much smaller, but had a somewhat similar appearance. However, the examination of the cheeks revealed a lesion consisting of a series of pearl-gray "white lines," superficially situated in the bicuspid-molar area at about the occlusal-plane line of the teeth, arranged in a net-like mosaic (*fig. 5*). These had been overlooked by the physician. Examination of the larynx revealed four, small, oval-shaped, transparent lesions on a purplish-red base upon the epiglottis. The cords were swollen in the center. The condition was diagnosed as lichen planus of the tongue, cheek, and larynx. This opinion was confirmed by a prominent dermatologist. Careful examination of the skin revealed a single, small, papule on the flexor surface of the right wrist.

*Case 4.* Miss E. I., nurse, age 33, came with her dentist for consultation regarding the condition of her tongue. Although she was under treatment, she felt that a further confirmatory diagnosis would give her peace of mind. (Usually the fear of having a cancer of the mouth is the underlying disturbing thought.) The patient had first noticed four white patches on the tongue nine months ago. Since then, in spite of medical treatment, the patches have continued to spread. Examination showed that the anterior two thirds of the dorsal surface of the tongue, except the small margin of the periphery, was covered superficially by small raised patches set close together, of a distinct mother-of-pearl gray color (*fig. 6*). On the left cheek, in the molar region at about the occlusal line of the teeth, were three small, almost parallel, grayish-white lines set superficially in the mucous membrane. No other symptoms were present. Blood exami-

nations were negative. Skin examinations, made about nine months ago and again recently, were negative for lichen planus lesions.

*Comment.* By most physicians and dentists, lichen planus is considered to be a skin disease that occasionally presents oral-mucosa manifestations, whereas a study of the literature reveals the fact that the disease usually is attended by lesions of the oral mucous membrane. According to Trautman (2), who in 1911 made a study of 157 cases,

129 or 82 per cent of all cases showed lesions on the cheek
80 or 50 per cent of all cases showed lesions on the tongue
35 or 22 per cent of all cases showed lesions on the lips
27 or 17 per cent of all cases showed lesions on the palate
17 or 10 per cent of all cases showed lesions on the gums
7 or 4 per cent of all cases showed lesions on the larynx.

Trautman further showed that, in

94 or 62 per cent of the cases, the skin and oral mucous-membrane lesions occurred approximately simultaneously; in
26 or 17 per cent of the cases, only oral mucous-membrane lesions were found; in
19 or 12 per cent of the cases, the skin lesion appeared first and was followed by oral mucous-membrane signs; and in
14 or 9 per cent of the cases, the oral mucous-membrane lesion appeared first, to be followed by skin signs.

Thus we see that, in a relatively large percentage of cases (approximately 26 per cent), the oral mucosa may be involved first, then skin lesions may follow, or there may be no skin manifestations.

The appearance of the lichen-planus lesions noted in the four cases cited above are good examples of lichen planus of the mouth. The lesions are usually mother-of-pearl gray in appearance, and consist of raised papules or polygonal patches; or the disease may assume a lace-work mosaic and, in some cases, resemble the male fern-leaf configurations.

### III. PEMPHIGUS

Pemphigus is commonly considered to be a skin disease, yet frequently it begins in the mouth or on the lips. Often such cases are undiagnosed until the subsequent appearance of skin lesions. In the

presence of primary skin lesions the diagnosis is usually simple. The disease is characterized by bleb or bullae formations containing a bloody secretion.

*Case 5.* Mrs. R. I., age 49, Jewish, born in Russia. Six weeks ago her lips became swollen and she had bleeding from the gums. White patches then formed on the lips, and on the cheeks and palate. At first she felt very little pain. She also complained of belching. Her gastro-intestinal tract was examined by a gastro-enterologist and "ruled out." Later she developed difficulty in swallowing. She was sent to a hospital. While there, the lesions were painted with silver nitrate, but this treatment did not seem to be effective. Vincent's infection was then considered, as smears showed numerous fusiform bacilli and spirillae. When I first saw the patient, her teeth were in very poor hygienic condition, the gums spongy, and the cheek and palate covered with several blebs in various stages of development and destruction. In some areas, large amounts of grayish slough that could be removed easily revealed markedly inflamed raw surfaces. She said that these crops of blisters would form again when removed. By this time, she had lost considerable weight owing to inability to eat comfortably. She complained of considerable difficulty in swallowing, and of sleeplessness owing to fear of choking to death.

A diagnosis of pemphigus was made. Careful search of the skin showed no skin manifestations. She was given hot, sodium-perborate, mouth irrigations, which seemed to relieve her somewhat for a time. She also received various arsenic compounds locally and internally, but without much relief. About two months later I referred her to Dr. George MacKee, a prominent dermatologist, who confirmed the pemphigus probability, and also presented her before the Dermatology Section of the New York Academy of Medicine, where the same opinion was expressed. The patient died several months later, which tended to confirm the diagnosis. So far as we know she presented no skin lesions; certainly her mouth manifestations were primary.

*Comment.* In the case of primary pemphigus, or when restricted to the oral mucous membrane, the early symptom often is a burning pain in the neck, with intense inflammation or redness. Later, usually swelling and hemorrhage appear with bleb formations, which come

and go in crops. Examination during such a time shows these blebs in various sizes and stages of development and destruction, with grayish tabs of epithelium-slough when the blebs are macerated. In the early cases, when the pemphigus persists as an inflammatory phenomenon of redness and swelling, the clinical signs are not characteristic, as it resembles many other forms of angina.

Characteristic symptoms of pemphigus are persistent constitutional disturbances, loss of weight, inability to sleep, difficulty in swallowing, and a sensation of choking to death. Blood smears usually show a high eosinophilia. Pemphigus, while usually fatal, has its period of remissions, which should caution one against giving a too favorable prognosis.

While attending Professor Artz's Clinic in Vienna, I saw two cases of pemphigus: one, in an old man who had blisters on the entire lower lip, with a few blisters inside his mouth, on the cheek and on the soft palate. These blisters were very painful. No skin lesions were present. His blood picture showed 40 per cent eosinophilia. The other case was that of a middle-aged woman who had blebs on the face, lip, and skin, some of which had become encrusted (*fig.* 7). There were no mouth manifestations.

Pemphigus must be differentiated from herpes. Trautman (2), in his study of 222 reported cases, showed that, in

65 or 29.2 per cent of all the cases, the oral mucous-membrane lesions were primary, and were followed by skin manifestations; in

53 or 23.8 per cent of all the cases, only oral mucous-membrane lesions were found; in

54 or 24.3 per cent of all the cases, the skin lesions were primary; and in

50 or 22.5 per cent of all the cases, the skin and oral mucous-membrane lesions occurred approximately simultaneously.

If considered in the order of frequency, the oral mucous membrane was involved as follows: cheek, 60 per cent; palate, 41 per cent; pharynx, 35 per cent; tongue, 31 per cent; gums, 10 per cent. From a study of the 222 reported cases, we see that over 50 per cent showed mucous-membrane involvement first.

## IV. HERPES SIMPLEX

Herpes simplex (fever blister) is a skin disease of an acute inflammatory nature characterized by groups of vesicles upon an inflamed area, probably owing to nerve changes. Herpes, as it occurs on the face and lips, is very well known to the average dentist and layman. That the same type of herpes simplex can occur in the mouth, on the mucous

FIG. 8. Herpes simplex of palate

membrane of the cheek (herpes buccalis), tongue (herpes lingualis), tonsil (angina herpetica), gum, palate, larynx, or on the genitalia and anus, is perhaps not so commonly known. However, of great importance to the dentist is the fact that it may occur in the mouths of patients following procaine injection for the extraction of a tooth. From an etiologic standpoint, two types of herpes simplex have been described: one, idiopathic, is not based upon infection and is less

common; the other, symptomatic, is usually an expression of constitutional infectious disease, such as cerebro-spinal meningitis, pneumonia, influenza, or common cold of the nose, and is the more frequently observed. The latter group is subdivided usually into the recurrent and non-recurrent forms. The non-recurrent forms of herpes simplex are usually considered to be either (a) traumatic in origin, probably owing to a produced neuritis or perineuritis; or (b) expressions of menstrual disorders, especially in herpes vulva; or (c) neurotrophic disturbances.

In 1926, I described a case of herpes simplex of the palate in a woman convalescing from influenza, following a procaine injection for the extraction of a tooth (3). The following is another case of possible traumatic neuritis or perineuritis, as seen recently after procaine anesthesia.

*Case 6.* Mrs. R. G. had an upper left molar extracted under procain anesthesia. Forty-eight hours later she complained of pain. A cluster of small, pin-head ulcerations was observed on the hard palate near the site of extraction (*fig. 8*). These ulcerations were treated with 10 per cent silver nitrate solution, which relieved her symptoms. The patient was well otherwise, and gave no history of any recent illness.

*Comment.* In the case previously described by me (3), and in this, the patients complained of symptoms that usually accompany herpes simplex of the mouth. Herpes of the skin is usually free from symptoms. In a case described by Pohl (4), occurring in a young girl following a procaine mandibular injection, there were no complaints. The lesions observed were a cluster of small blisters on the cheek and a large blister on the lip. The symptoms of pain, or the burning sensations that commonly occur, are considered to be due to secondary infection caused by oral bacteria.

Herpes simplex must be differentiated from acute pemphigus of the mouth, according to Glas as shown in the summary on the next page (5).

| *Herpes simplex of the mouth* | *Acute pemphigus of the mouth* |
|---|---|
| The blisters are pin-point to large pin-head in size | The blisters vary in size—from pea-size to bullae |
| These blisters contain a serous fluid | The blisters contain a sero-hemorrhagic fluid |
| The blisters are usually macerated during the first 24 hours. When the ulcerations are observed, no traces of the epithelial dome of the blisters remain | The blisters are macerated quickly, some in one-half hour; are seen in various stages of development and destruction; and usually tabs of epithelial debris are present or a slough is formed |
| No evidence of hemorrhage or symptoms of argina are present | Evidence of hemorrhage; usually accompanied by acute inflammation of the larynx and the pharynx |

Glas, in his study of 14 cases of herpes simplex of the mouth, found in 9 cases the following bacteria: 4 showed staphylococcus albus; 2, staphylococcus aureus and albus; 3, streptococci. These findings were similar to those of other investigators. However, in his fourteenth case he found, in the blisters as well as on the pharynx and larynx, large masses of Vincent organisms—fusiform bacilli and spirillae, together with streptotocci.

## V. SUMMARY

(1) Skin and mucous membranes are derived from the same embryonal structure—the ectoderm. Hence, similar lesions in both tissues may be due to the same disease.

(2) Often the mucous membrane of the mouth is the site of primary lesions which may or may not be followed by skin manifestations. In lichen planus, approximately 26 per cent of oral mucous-membrane lesions are primary; in pemphigus, approximately 50 per cent.

(3) Several cases of primary lichen planus, pemphigus, and herpes simplex are cited.

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# THE OCCURRENCE OF MOTTLED ENAMEL AMONG THE CHINESE[1]

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The abnormality of the teeth known as mottled enamel has aroused considerable interest in the dental profession during the past decade and a half. According to Eager (1902) this condition was first brought to the attention of the profession by Chiaie (?) of Naples. It did not receive wide attention, however, until McKay (1916) reported it as occurring endemically in certain regions of Colorado. Black (1916), in collaboration with McKay, published the results of a histological study of the enamel of mottled teeth. According to Black the condition presents two distinct aspects: (a) an opaque chalky appearance of the enamel, due to a failure of deposition of interprismatic cement-substance during the developmental period; and (b) the impregnation of this defective enamel, after eruption of the teeth, with a stain designated by Black as "brownin." The degree of chalkiness or brownin staining was noted separately during the examination of these individuals.

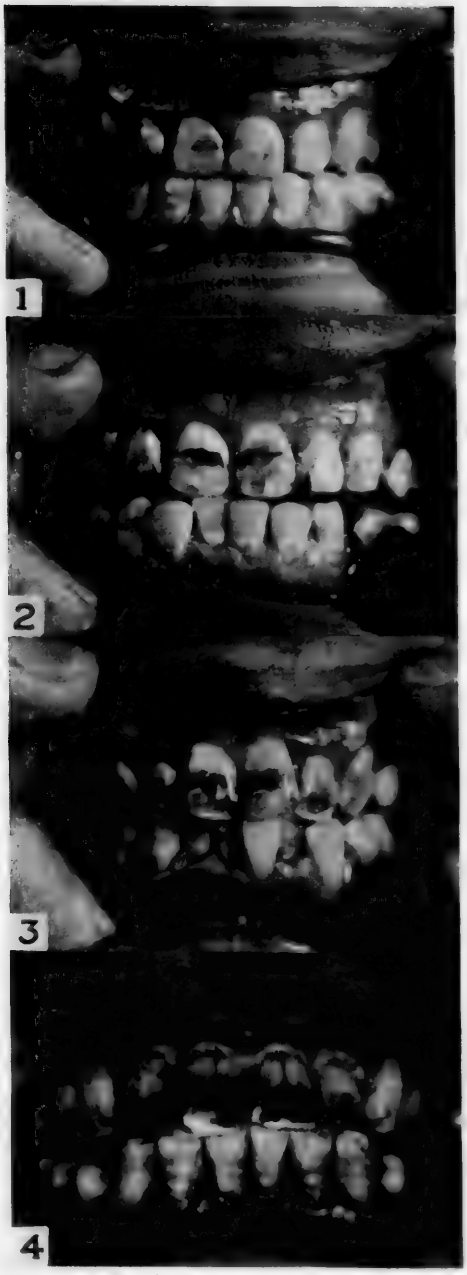
The exceedingly common occurrence of mottled enamel among the Chinese, at least in North China, is worthy of note. Observations on over five thousand patients in the dental clinic of the Peiping Union Medical College, as well as reports from physicians practising in various parts of North China, indicate a rather wide-spread distribution of the condition over this region in general. Endemic centers, however, also exist. One such center, the report of which will provide the subject of a separate communication, was recently visited by one of the authors (B. G. A.) who found the condition present in practically 100 per cent of the local population.

[1] Read at a meeting of the New York Section of the International Association for Dental Research, at the School of Dental and Oral Surgery, Columbia University, March 13, 1930.

The present report deals with certain statistics bearing upon the relative incidence of the condition in two distinct geographical regions: namely Peiping and Taiyuanfu, including their respective immediate environs. The former region is located at the northern end of the Chihli plain, while the latter is some four hundred miles distant on the Shansi plateau. The observations in the first instance were made on clinic patients, school children, college students, soldiers, and laborers. The Taiyuanfu observations were restricted largely to locally (central Shansi) recruited police examined during a joint anthropological reconnaissance in Shansi by the two authors in 1924. Records of observations on over five hundred individuals are available for the study in hand. In each person the presence or absence of both chalkiness and brownin staining is recorded according to the scale 0, 1, 2, 3, 4, where 0 indicates total absence of the condition and 4 its most marked form (*figs. 1–4*). All observations were made by the senior author (B. G. A.), while the statistical treatment of the data is that of the collaborator (P. H. S.).

We will first consider the geographical factor. *Table 1* gives the percentage incidence of the respective conditions in the two localities compared. In both cases the percentages show differences which, having regard for the probable errors of the differences, are statistically significant. Thus the figures for chalky enamel show that while the condition was present in a considerable majority of all individuals examined in both regions, the percentage incidence of the condition in Taiyuanfu is significantly higher than in Peiping. Also, the percentage incidence of brownin staining, while somewhat lower in both regions, is again significantly higher in the Taiyuanfu population. The contention of Black (1916) that these two conditions are closely related apparently finds support in the general parallelism exhibited by these figures. In addition, a measure of geographical control in the distribution of the two associated conditions seems to be clearly indicated.

Turning next to a consideration of the age factor, we have in *Table 2* the age-distribution for the whole of the material, i.e., without regard to geographical distribution. The age-groups chosen represent convenient divisions of age from the time of the eruption of the permanent dentition through the periods of later childhood, adolescence, and




FIGS. 1–4. Photographs showing consecutively the degrees of mottled enamel on the scale of 1 to 4, inclusive. (Page 234.)

maturity. Although the numbers in the different age-groups are rather small, and the probable errors consequently large, the figures are nevertheless of considerable interest. In the case of chalky enamel a definite decrease in the percentage incidence, as the higher age-groups are approached, is clearly shown. For the brownin stain, a division of our first two age-groups into smaller units would probably show a gradual increase during later childhood and adolescence, while the decrease in percentage incidence in the later periods follows that of the chalky enamel.

TABLE 1

*Absolute and relative incidence of (a) chalky and (b) brownin-stained enamel in Peiping and Taiyuanfu*

| LOCALITY | TOTAL NO. EXAMINED | (a) CHALKY ENAMEL | | TOTAL NO. EXAMINED | (b) BROWNIN STAINED | |
|---|---|---|---|---|---|---|
| | | No. | Percentage | | No. | Percentage |
| Peiping | 398 | 272 | 68.34 ±2.33 | 393 | 90 | 22.90 ±2.12 |
| Taiyuanfu | 109 | 90 | 82.57 ±3.63 | 108 | 49 | 45.37 ±4.79 |

TABLE 2

*Absolute and relative occurrence of (a) chalky and (b) brownin-stained enamel among the Chinese according to age*

| AGE GROUP | TOTAL NO. EXAMINED | (a) CHALKY ENAMEL | | TOTAL NO. EXAMINED | (b) BROWNIN STAINED | |
|---|---|---|---|---|---|---|
| | | No. | Percentage | | No. | Percentage |
| *years* | | | | | | |
| 7–15 | 196 | 151 | 77.05 ± 3.00 | 192 | 53 | 27.60 ±3.23 |
| 15–25 | 239 | 175 | 73.22 ± 2.86 | 235 | 73 | 31.60 ±3.00 |
| 25–35 | 54 | 29 | 53.70 ± 6.78 | 57 | 11 | 19.30 ±5.23 |
| 35– | 18 | 7 | 38.89 ±11.49 | 17 | 2 | 11.76 ±7.81 |

*Table 3* presents a further subdivision of the individuals in the different age-groups according to the varying degrees of the two conditions found in each period. The figures of this table show that not only does the incidence of each condition as a whole decrease with age (*Table 2*), but the remaining cases in the higher age-groups are increasingly those of the milder degrees of manifestation. From a consideration of the general nature of mottled enamel it is hardly to be expected that the condition spontaneously disappears with advancing years. The present authors are inclined to interpret the above findings

regarding age incidence as indicating that mottled enamel is part of a syndrome of constitutional defect, probably of early malnutritional origin, and the diminished occurrence of the condition among those in the more advanced age-groups merely reflects the selective discrimination of diseases in general against the portion of the population thus affected. In other words it seems that a larger proportion of those without the condition survive to full maturity and later age than

TABLE 3

*Occurrence of different degrees of (a) chalky and (b) brownin-stained enamel according to age*

| AGE GROUP | (a) CHALKY ENAMEL | | | (b) BROWNIN STAINED | | |
|---|---|---|---|---|---|---|
| | Degree | No. | Percentage | Degree | No. | Percentage |
| *years* | | | | | | |
| 7–15 | 1 | 80 | 52.98 ± 4.06 | 1 | 40 | 75.47 ± 5.91 |
| | 2 | 54 | 35.76 ± 3.90 | 2 | 10 | 18.87 ± 5.37 |
| | 3 | 17 | 11.26 ± 2.57 | 3 | 3 | 5.66 ± 3.18 |
| | 4 | 0 | | 4 | 0 | |
| 15–25 | 1 | 97 | 55.43 ± 3.76 | 1 | 51 | 69.86 ± 5.37 |
| | 2 | 63 | 36.00 ± 3.63 | 2 | 18 | 24.66 ± 5.04 |
| | 3 | 10 | 5.71 ± 1.75 | 3 | 2 | 2.74 ± 1.92 |
| | 4 | 5 | 2.86 ± 1.59 | 4 | 2 | 2.74 ± 1.92 |
| 25–35 | 1 | 19 | 65.52 ± 8.83 | 1 | 7 | 63.64 ±14.50 |
| | 2 | 8 | 27.59 ± 8.30 | 2 | 4 | 36.36 ±14.50 |
| | 3 | 2 | 6.89 ± 4.70 | 3 | 0 | |
| | 4 | 0 | | 4 | 0 | |
| 35– | 1 | 5 | 71.43 ±17.07 | 1 | 2 | 100.00 ± 0.00 |
| | 2 | 1 | 14.28 ±13.22 | 2 | 0 | |
| | 3 | 1 | 14.28 ±13.22 | 3 | 0 | |
| | 4 | 0 | | 4 | 0 | |

of those with it. Although no direct causal relationship is implied in this statement, nevertheless specific investigations as to the correlation of mottled enamel with other manifestations of constitutional deficiencies, or with diseases affecting the young, would be of considerable interest and value.

## SUMMARY

The common occurrence of mottled enamel among the Chinese is reported for the first time. While generally distributed over the whole

of North China, the significantly higher incidence of the condition in certain regions is shown by a statistical comparison of observations made in two widely separated centers. A gradual decrease in percentage incidence of the condition among individuals in the later age-groups of the population is noted. This observation leads the authors to suggest that the condition in question is most probably a manifestation of constitutional deficiency. The need of correlational studies on the occurrence of mottled enamel in connection with other morbid conditions affecting individuals in the adolescent period is emphasized.

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# A LEAD SECTOR-DISK FOR EXPRESSING DENSITY OF BONE AND TOOTH STRUCTURE IN TERMS OF PERCENTAGE TRANSMISSION OF X-RAYS[1]

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## I. INTRODUCTION

Attempts to determine densities of bone and teeth by means of an x-ray method have been made by few workers. Doubrovine[2] has reported a method consisting primarily of crude comparisons of x-ray films photometrically without any attempt at calibration. More recently Bishop and Warren[3] have advocated a method in which aluminum step-tablets are used as a calibration standard for determining bone densities. In their method, the bone densities are determined by comparing the density of photographic deposits produced by x-rayed bone with that produced by various thicknesses of sheet aluminum. The densities are then expressed in terms of millimeters of aluminum.

In a study of the effects of dietary deficiencies upon bone and tooth structure in swine, it became necessary to evaluate tooth and bone

[1] Presented at a session of the Eighth General Meeting of the International Association for Dental Research, Toronto, Canada, March 24–26, 1930.

Aided by grants from the Dental Staff of the Johns Hopkins Hospital, and the Research Commission of the American Dental Association.

[2] Doubrovine: *Revue de Stomatologie*, 1928, xxx, p. 154.

[3] Bishop and Warren: *American Journal of Roentgenology and Radium Therapy*, 1929, xxi, p. 229.

density. Of the methods described above, the first is inadequate for expressing bone and tooth densities in quantitative and direct units of opaqueness to x-rays. The second expresses densities in terms of an arbitrary standard. For our purpose, a special lead sector-disk

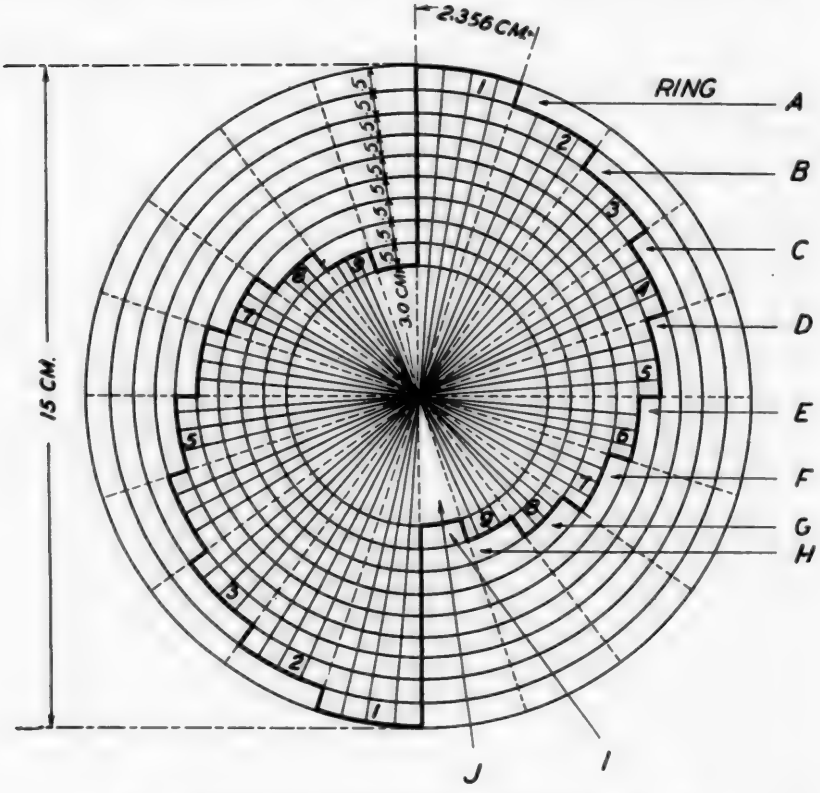


FIG. 1. Drawing illustrating the method of preparing lead sector-disk

was designed by means of which density may be expressed directly in terms of percentage of x-ray transmission.

The difficulties involved in comparing structures on one film with those upon another, taken at a different time, are eliminated by photographing the calibration disk upon the same film with the bone

or tooth. Densities of the silver deposits in the several rings are then compared with the density of the silver deposit representing the tooth or bone structure. These densities are expressed in terms of percentage x-ray transmission.

## II. DESCRIPTION OF LEAD SECTOR-DISK

The calibration-disk, used for comparing bone and tooth densities with those of varying thicknesses of lead, is cut from a flat piece of sheet lead, $\frac{1}{32}$th of an inch thick. The diameter of the disk is 15 cm. Ten concentric circles are then described upon the lead disk, each concentric circle having a radius 0.5 cm. less than that of the adjacent outlying circumference as indicated in *fig. 1*. The outer circumference is then divided into twenty arcs of equal length. Radii are described from each division of the outer circumference to the center of the disk. This procedure divides the disk into twenty sectors of equal radii and arcs of equal length. That portion of the area of sectors 1 and $1^1$ included in ring A, then constitutes 10 per cent of the total area of ring A. The remaining 90 per cent is then cut away. That portion of the area of sectors 1, 2, $1^1$, $2^1$, included in ring B, constitutes 20 per cent of the total area of ring B. The remaining 80 per cent is removed. That portion of the area of sectors 1, 2, 3, $1^1$, $2^1$, $3^1$, included in ring C, represents 30 per cent of the total area in ring C. The remaining 70 per cent is cut away. That portion of the area of sectors 1, 2, 3, 4, $1^1$, $2^1$, $3^1$, $4^1$, included in ring D, constitutes 40 per cent of the total area of ring D. The remaining 60 per cent is removed. That portion of the area of sectors 1, 2, 3, 4, 5, $1^1$, $2^1$, $3^1$, $4^1$, $5^1$, included in ring E, constitutes 50 per cent of the area of ring E. The residual 50 per cent is removed. That portion of the area of sectors 1–6 and $1^1$–$6^1$, inclusive, contained in ring F, constitutes 50 per cent of the total area of the ring. The residual surface of the ring is cut away. That portion of the area of sectors 1–7, and $1^1$–$7^1$, inclusive within ring G, constitutes 70 per cent of the area of the ring. The remaining 30 per cent of the area is cut away. That portion of the area of sectors 1–8 and $1^1$–$8^1$ inclusive, within ring H, constitutes 80 per cent of the surface of the ring. The remaining 20 per cent is removed. That portion of the area of sectors 1–9 and $1^1$–$9^1$, inclusive, within ring I, constitutes

90 per cent of the total area of ring I. The remaining 10 per cent is cut away. All twenty sectors are included in ring J, which has no surface removed, and so presents a 100 per cent surface-area of lead.

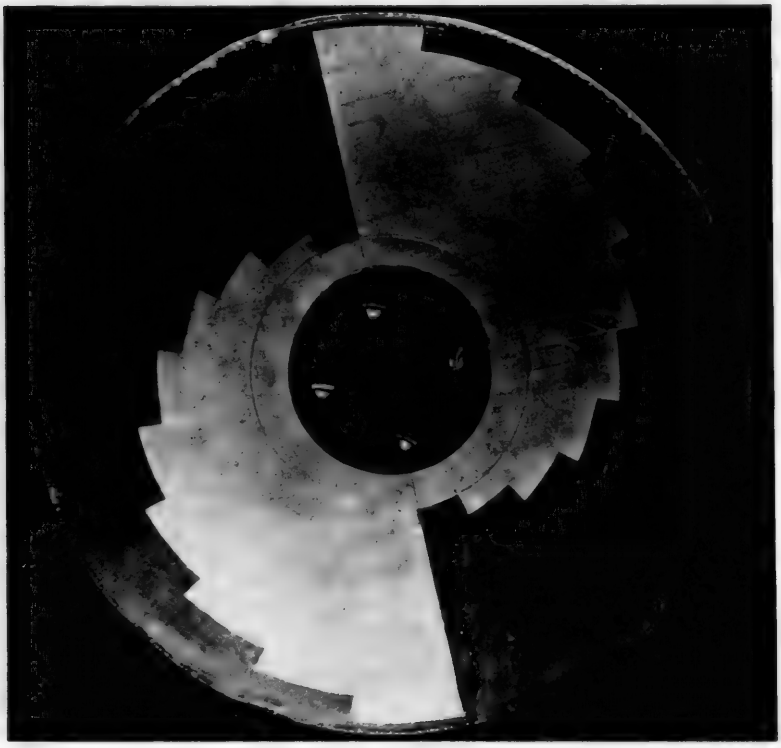

FIG. 2. Photograph of mounted disk

The disk cut according to the above outlined specifications and mounted is shown in *fig. 2*.

When the disk is revolved upon a firm glass base,[4] with a minimum of vibration present, each ring presents a homogeneous mixture of a

[4] This thin glass base was a negligible factor in obstructing the transmission of the x-rays, since the rays which might have been stopped by the base had already been filtered by the glass of the tube.

definite percentage of a substance opaque to x-rays and a definite percentage of a substance transparent to the rays. The homogeneous mixtures of the lead portion of the rings and of the non-lead portion are best illustrated by a photograph of the different intensities of x-ray produced when the disk is rotated rapidly as shown in *fig. 3*.[5]

### III. EXPERIMENTAL METHOD

With the sector-disk revolving at a speed of approximately 500 revolutions per minute, the objects to be x-rayed are placed upon the film outside the area covered by the disk. An exposure is then made of 40 seconds at 5 milliamperes with a 1.5 inch spark-gap at a target distance of 25 inches, using a 30-milliampere median-focus Coolidge

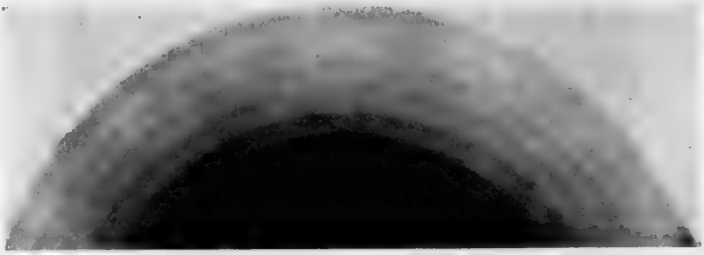

FIG. 3. Various shades of gray produced by different contents of lead within the sector disk illustrating the homogenous mixture of opaque and transparent portions of the rings.

tube. Typical x-ray photographs taken by the above-outlined procedures are shown in *fig. 4*.

The difference in density of the rachitic bone (*fig. 4*), as compared with normal alveolar bone from animals of approximately the same size, is particularly striking. When the alveolar bone of the animal upon the control diet is compared with the lead sector-disk, the density or opaqueness of the bone to the x-ray penetration may be expressed as equivalent to approximately 80–90 per cent of lead $\frac{1}{8}\frac{1}{4}$th inch thick. In terms of transmission, the bones from these animals permit penetration by 10–20 per cent of the x-ray produced.[6]

[5] It should be noted that the varying percentages of lead in the rings serves essentially as a time-shutter, giving varying times of exposure of a definite number of x-rays in each ring.

[6] Using the above-indicated x-ray exposures, no photographic deposit is observed in ring J. This indicates that ring J permits the penetration of zero per cent of x-rays.

In contrast, it is found that the density or opaqueness of the bone to x-ray penetration of alveolar bone of animals upon low-calcium diets is equivalent to less than 10 per cent of lead $\frac{1}{84}$th inch thick. In

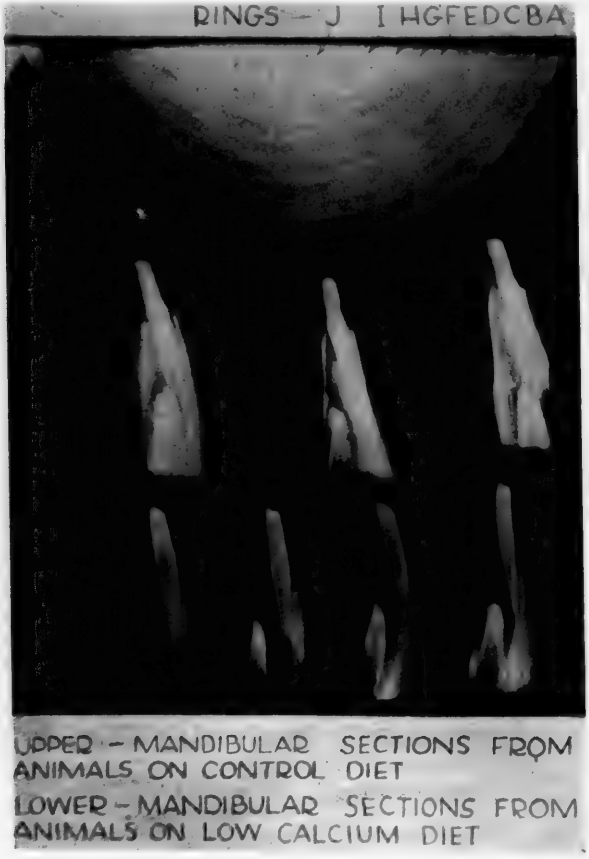
RINGS – J I HGFEDCBA
UPPER – MANDIBULAR SECTIONS FROM ANIMALS ON CONTROL DIET
LOWER – MANDIBULAR SECTIONS FROM ANIMALS ON LOW CALCIUM DIET

FIG. 4. X-ray photographs of incisor teeth in alveolar bone of normal and rachitic animals of approximately same age, made simultaneously upon the same film upon which photograph of revolving disk is made.

terms of percentage transmission, the bone from the low-calcium animals permits penetration by between 90 and 100 per cent of the x-rays produced.

In comparing tooth densities from normal and rachitic groups by this procedure, differences are not so readily perceived. The finding of such differences, should they exist, must await further refinement of the method, work upon which is now in active progress.

## IV. DISCUSSION

It becomes apparent that no attempt has been made in this preliminary report to express densities photometrically. The method, as presented in this communication, is limited to a semi-quanitative comparison of alveolar bone and tooth with various portions of the lead sector-disk. The results of work now in progress—on a special densitometer method with which photographic tracings are made of the densities of tooth, bone, and sector-disk—will be reported in a succeeding communication.

Appreciation is expressed to Mr. Patrick Bergin for assistance; and to Dr. Janet Clark for kindly permitting the use of certain parts of her x-ray equipment.

# *Quotations Relating to "Dentistry or Stomatology"*

THIS JOURNAL uses the term "dentistry" to signify the science and art of oral health service in all its local and systemic relationships. The meanings of words, which are not necessarily restricted to *etymological* significance, acquire expanded or new import in accordance with convenience and usage. Thus the term "medicine," which originally meant to remedy or cure, now also means *to make remedial or curative treatment unnecessary.* "Stomatology" is a synonym for "dentistry." We prefer the older term because its use respects both the history of dentistry and the efforts of those who have brought dentistry to its present status.—*Journal of Dental Research*, 1929, ix, p. iii.

If dentistry were merely dental mechanics, a two-year course in dental technology, based on graduation from a high school and conducted along lines similar to those for the education of optometrists, would probably afford sufficient training for dental practice, and oral health-service could be reserved for a new specialty to include oral surgery, which might be named stomatology and made analogous to ophthalmology and other specialties of medicine. But with dentistry developed into the *full service equivalence* of an oral specialty of medicine, the creation of a medical specialty of stomatology would be redundant—and there would be no occasion to substitute "stomatology" for the name established by custom.—*Carnegie Foundation's Bulletin on Dental Education*, 1926, p. 135.

The assumption that dentistry would be something more or better than it is, if all or a part of it were called "stomatology," exemplifies a readiness to attach more importance to labels than to contents, or more significance to make-believe than to reality. The term "medicine" originally meant to remedy or cure. ["*Medicina* (ars)"—healing art; "*medicina* (res)"—a remedy; "*medicus*"—of healing; also a physician.] Today "medicine," by including measures to *prevent* sickness and by throwing *etymology* overboard, means not only to remedy or cure, but also *quite the contrary*—to make remedial or curative treatment unnecessary. As medical knowledge has advanced and medical procedures have been changed in consonance, including the development of prevention and of surgery, new meanings have been imparted to the term "medicine." But instead of replacing "medicine" by a succession of words intended to indicate *etymologically* the broader or deeper modern meanings, the import of the original term has been conveniently enlarged as the scope of medical practice has expanded. Thus, the term "medicine" has come to mean more and more as *physicians*, without restricting themselves to its *etymology*, have included *more and more in its significance.* Along the same line of reasoning one sees clearly that, although *etymologically* the term "dentistry" refers only to the teeth, nevertheless logically it also comprehends the contiguous parts and their systemic relationships. Certainly by *usage* in conformity with this logic, and also with the criteria of common sense, the term "dentistry" has *acquired* the broader meaning suggested by the more detailed and lengthy term "oral health-service." By logic, usage, and convenience, the term "dentistry" has thus become the *practical* equivalent of "stomatology," which *etymologically* means the sum of scientific knowledge concerning the mouth, but *etymologically does not include the rest of the body* (although "stomatology" is now *used* by some to include systemic relationships with the mouth). This being true, we are unable to agree that "dentistry" and "dentists," which are terms that have long represented the earnest and aspiring endeavors of generations of faithful practitioners of oral health-service, should be formally replaced for *etymological* reasons by "stomatology" and "stomatologists."—*American College of Dentists*, March, 1929.

The New York Academy of Dentistry . . . without any diminution of its abiding purpose to promote intimate association and cooperation between dentists and the practitioners of all other kinds of health-service, believes that, in the interest of the patient, dentistry should be *continued* as a separately organized profession, based on systems of ethics, education, jurisprudence, and journalism that will fully meet all public needs at each stage of its evolution.—*New York Academy of Dentistry, April, 1929.*

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